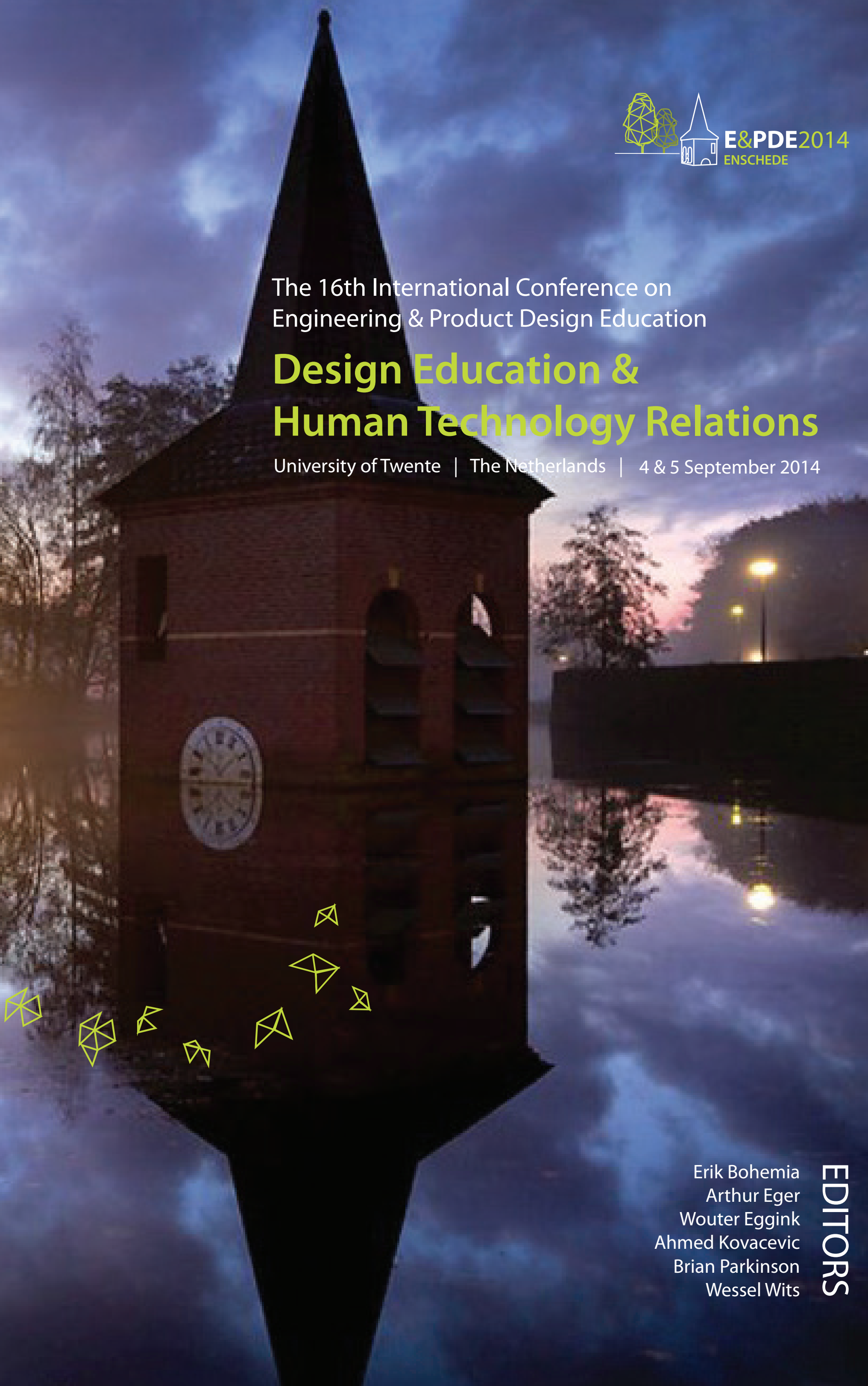

E&PDE2014 ENSCHEDE

The 16th International Conference on Engineering & Product Design Education

# Design Education & Human Technology Relations

University of Twente | The Netherlands | 4 & 5 September 2014

EDITORS
Erik Bohemia
Arthur Eger
Wouter Eggink
Ahmed Kovacevic
Brian Parkinson
Wessel Wits

# Design Education & Human Technology Relations

Editors: Erik Bohemia, Arthur Eger, Wouter Eggink, Ahmed Kovacevic,
Brian Parkinson and Wessel Wits

PROCEEDINGS OF THE 16TH INTERNATIONAL CONFERENCE
ON ENGINEERING AND PRODUCT DESIGN EDUCATION,
UNIVERSITY OF TWENTE, ENSCHEDE, THE NETHERLANDS
4TH – 5TH SEPTEMBER 2014

# Design Education & Human Technology Relations

**Erik Bohemia**
Loughborough University, Design Education Society
Special Interest Group, Design Society

**Arthur Eger**
University of Twente

**Wouter Eggink**
University of Twente

**Ahmed Kovacevic**
City University, Design Education Society Special Interest Group,
Design Society

**Brian Parkinson**
Institution of Engineering Designers

**Wessel Wits**
University of Twente

Cover Credit: Maaike Mulder-Nijkamp



**Institution of Engineering Designers**
Courtleigh, Westbury Leigh, Westbury, Wiltshire, BA13 3TA, United Kingdom
+44 (0)1373 822801
www.ied.org.uk

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**The Design Society**
University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ, United Kingdom

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# Foreword

# DESIGN EDUCATION & HUMAN TECHNOLOGY RELATIONS

The 16th International Conference on Engineering and Design Education (E&PDE) was held at the University of Twente on the 4th and 5th September 2014.

The conference was hosted by the Faculty of Engineering Technology of the University of Twente in Enschede, the Netherlands, in close collaboration with the Design Education Special Interest Group (DESIG) of the Design Society and the Institution of Engineering Designers (IED).

The E&PDE conference was initiated in 1999 in the United Kingdom and was consolidated as an international conference in 2004; alternately taking place in the UK and abroad. Its objective is to facilitate the bringing together of people from within education and industry who are interested in sharing expertise on the implementation and analysis of contemporary and developing methodologies in engineering and design education. It provides educators and researchers from product development, engineering and industrial design, together with industry and government representatives, with a platform for discussion on topical educational issues in design education and its future direction.

## Conference Theme

As the host institution for E&PDE 2014 we chose to focus on the influence of technology on human behaviour and vice versa. We developed the theme of Design Education & Human Technology Relations in the knowledge that product designers and engineers influence human behaviour with their designs. This influence works in two directions. Designers develop products and services that help people in their functioning in daily life, that are tools for them to use. However, these tools often also change the behaviour and possibilities of their users. New and faster ways of transportation helped people to get to their work, family and friends, but it also gave them the possibility to live further away from their work. This created new phenomena, such as traffic lights and traffic jams. More recent, the internet made letters almost obsolete. More and more designers start to realize that their designs can have unexpected, and sometimes even unwanted consequences. Therefore it is important that design educators explore the interrelationships between engineering and technology, and behavioural, societal, cultural and ethical issues.

Our aims with the theme Human Technology Relations are to:

- Provide a networking platform for a broad variety of participants
- Explore how engineering and product design education contributes to a balanced development of technological opportunities and the needs of people for future society
- Discuss how engineering and product design education can lead to meaningful products for a world that is mediated by technology
- Explore how the focus on human technology relations can contribute to the development of creativity and design success
- Discuss how design education may best be used to address the social and ethical aspects of technology
- Seek innovative solutions for a better world through "best practices" in engineering and design education
- Embed the integration of all aspects of engineering and design in our curricula
- Explore the broadening and deepening of student experiences through international exchange

**Conference Programme**

25 countries will be represented at the Conference this year. 229 contributions were received which explored the full depth and diversity of the conference theme. Amongst them were 55 student contributions. After reviewing abstracts, full paper submissions and subsequent revisions 120 contributions were selected to be included in the proceedings, of which 12 were poster presentations at the conference. The accepted papers allowed the committee to build a conference programme with a number of major streams including; Design Education Methods, Using Technology in Teaching, Creativity, Design Education and Design Cultures, Ethics and Emotions and International Collaboration. As such, the programme covers the issues and meets the needs that arose when the conference theme was defined.

Our keynote speakers Professor Peter-Paul Verbeek and Remko van der Lugt presented interesting lectures on the subjects Design for Society: Understanding and Evaluating the Relations between Humans and Technologies and Educating the Product-Service System Designer: A call for Engagement.

**Conference Host**

The E&PDE 2014 took place on the campus of the University of Twente and was hosted by the Faculty of Engineering Technology. The University is located in the eastern part of the Netherlands, between the towns of Enschede and Hengelo. The Faculty of Engineering Technology provides educational programmes in Mechanical Engineering, Industrial Design Engineering and Civil Engineering, with a strong focus on the integrative aspects in these domains. Furthermore was the Conference supported by Saxion University of Applied

Sciences in Enschede and the Department of Industrial Design Engineering of KIVI, the Royal Institution of Engineers in the Netherlands.

**Acknowledgements**

This 2014 edition of the E&PDE conference was made possible through the commitment and efforts of many people. I would like to thank Ahmed Kovacevic, Judith Grace, Brian Parkinson and Erik Bohemia for their excellent leadership in organizing this conference and their dedication to the common cause: guaranteeing a conference series of growing quality and impact. I am grateful for having had the opportunity to work with Alison Parker and Nadine Pearce from the Institution of Engineering Designers, the work of organizing the conference would have been much more onerous without the practical support, hands-on experience and in-depth knowledge which Alison and Nadine provided.

I would sincerely like to thank all the members of the international academic review board. They succeeded in the timely review of a vast number of papers, while retaining a true professional and academic stance on the intrinsic value and qualities of all papers submitted.

Naturally, I would like to express my gratitude to my colleagues from the Faculty of Engineering Technology – especially Wouter Eggink, Maaike Mulder, Pepijn van Passel, Juan Jauregui Becker and Wessel Wits, and especially our conference secretary Ans Fokkinga.

On behalf of the conference programme committee;

Arthur Eger
Head of the Department of Product Design

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The Design Society is an international non-governmental, non-profit making organisation whose members share a common interest in design. It strives to contribute to a broad and established understanding of all aspects of design, and to promote the use of results and knowledge for the good of humanity.
The Design Society was founded in 2000, taking on the previous activities and responsibilities of the Workshop Design Konstruction (WDK) Society, especially the organisation of the International Conference on Engineering Design (ICED) series of conferences, which had been running since 1981. Since 2000 the Society has organised ICED conferences in Stockholm, Melbourne, Paris, Stanford, Copenhagen and Seoul, with the 2015 event planned for Milan. It has also expanded with members from forty countries and with further very popular events such as the Engineering and Product Design Education conferences and the International Conference on Design Creativity among many other activities. The Society is very active in publishing papers and proceedings on design topics, and it has a developing portfolio of other design resources available to members including a repository of theses and collaborative agreements with a number of design research journals.

The Design Society concentrates on activities that transcend national boundaries, and, where possible, will seek to complement national activities.
The objects of the Society are to promote the development and promulgation of understanding of all aspects of design across all disciplines by:

- creating and evolving a formal body of knowledge about design;
- actively supporting and improving design research, practice, management and education;
- promoting co-operation between those in research, practice, management and education;
- promoting publications and their dissemination;
- organising international and national conferences and workshops;
- establishing Special Interest Groups and other specialist activities;
- co-operating with other bodies with complementary areas of interest.

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The Design Society is open to new members. www.designsociety.org

support
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Established in 1945, Incorporated by Royal Charter in 2012, the Institution of Engineering Designers is the only organisation in the UK to represent those working in the many fields of engineering and product design.

Our members enjoy a range of benefits, including advice on professional codes of conduct, a job board, regular newsletters to keep members up to date with relevant developments and events and a helpful legal advice line. We host regular events which offer our members the chance to network with other professionals and members receive the Institution's bi monthly journal – Engineering Designer.

We are committed to encouraging CPD for all our members, and support ongoing training and skills development.

We are licensed by the Engineering Council to assess candidates wishing to join the EC's Register of Professional Engineers and Technicians and we also accredit academic and training courses, both for membership of the Institution and registration with the EC. Those members who achieve the appropriate academic and competence standards receive Chartered Engineer, Incorporated Engineer or Engineering Technician status.

We are also a licensed body of the Society for the Environment and are able to register suitably qualified and competent members as Chartered Environmentalists (CEnv).

We welcome members from any organisation that has a design function and employs design engineers and we have many academic teaching staff in membership. The first step to becoming a member is to register as an Affiliate. You can find out more about becoming a member of the IED at:
http://www.ied.org.uk

Chapter 1

# DESIGN EDUCATION METHODS

# THE ROLE OF LEARNING- AND PRESENTATION-PORTFOLIOS IN DESIGN EDUCATIONS

**Bente Dahl THOMSEN and Nis OVESEN**
Department of Architecture, Design and Media Technology, Aalborg University

**ABSTRACT**
Students that primarily study design through team-based projects often struggle to develop presentation portfolios that differentiate from the ones of other students. In the industry, design managers experience this as a problem, as they often receive job applications with presentation portfolios that look very much alike. This raises doubts about the competences of the individual applicant. A solution to this problem could be to systematically generate more individual content in the form of learning portfolios throughout the design education. Based on limited knowledge about the implementation of the portfolio method in engineering design educations, this research project has investigated the method as part of a course programme. The preliminary experiments and results show that learning portfolio templates are effective in strengthening certain activities. On the other hand, the method risks draining resources from other activities, which is why the templates have to be carefully balanced in order to achieve the desired effect. The portfolio method proved to be especially good at illustrating process related competencies.

*Keywords: Portfolio methods, presentation portfolio, learning portfolio, industrial design engineering education*

## 1 INTRODUCTION

Managers of industrial design offices still expect that candidates for open positions and students looking for internships are able to present presentation portfolios that document their professional competencies. This is the conclusion of a series of visits and study trips to industrial design offices, where design managers have been encouraged to describe their respective requirements to applicants. The typical industrial design engineering educations rarely support the development of presentation portfolios directly. Thus, it seemed important to establish an overview of the requirements from the design offices and to investigate how portfolio development can be included in the educations.
*"The phenomenon 'portfolio' is as an artefact regarded to be influenced by the context, in which it is used, and by the meaning and purpose ascribed to the portfolio in the specific culture and organisation"* [1]. This is one of the central conclusions from the book "The Portfolio in a learning- and education-perspective" written by researchers and educators at the Department of Learning and Philosophy at Aalborg University. Within humanities, the portfolio method is closely related to the process of writing, reflecting and reformulating. It is not likely that design-engineering students will use these three terms to characterise their education despite the fact that project reports are an important part of it. However, from the interviews with eight design managers, it becomes clear that presentation portfolios related to the industrial design engineering practice are recommended to include on the following aspects:

1. Show who the applicant is as a person, including a photo and a CV, and bring forward the things that he/she is passionate about – also in the spare time.
2. Only show the things the applicant is proud of. The graphics have to be superb, and the quality of if should be expressed both aesthetically and in its function.
3. The material should be specifically selected in relation to the receiver, thus choosing a layout that allows for quick adjustment of the content.
4. Illustrate that the applicant can communicate both story and the process behind a product proposal through manual sketching.
5. It is critical to visualise knowledge about materials and production methods, e.g. through working drawings, wall thicknesses, curvatures, and drafting angles.

6. Include a case on product development with focus on project management and financial aspects.
7. Show that the applicant is able handle product details through the use of CAD.
8. Include a storyboard that demonstrates product testing through physical models like SLA, SLS or simple mockups.
9. Illustrate the applicant's competencies within the fields of LCA, service design and similar if the company is operating in those fields.
10. Show that the applicant can reduce the high level of abstraction by visualising products in real-life situations through photo essays.

The list above indicate that writing, reflecting and reformulating in relation to the design profession could be replaced by *sketching, testing,* and *developing*. The purpose of this paper is therefore to discuss the portfolio phenomenon in relation to design educations. More specifically whether or not the portfolio method has a special tenor, just as the learning portfolios and presentation portfolios of designers share more similarities with the ones from the visual arts rather than the ones from humanities.

## 2 THEORETICAL AND PRACTICAL BACKGROUND

The term *"learning portfolio" signals that the portfolio is used as a tool for study activities and learning and that it is not part for a formal evaluation* [2]. One of the purposes of introducing learning portfolios in the course "Experiment and process" on the 4$^{th}$ bachelor semester was to ensure that students were able to use theories and methods in practice and deal with specific challenges given to the students throughout the course. A series of exercises formed a type of template for the content of the learning portfolio. In the course the learning portfolio was the result of two group exercises (in project programming and ethical reflections) and four individual exercises (in semiotic analysis, semiotic design and CAD modelling of geometric and organic shapes). The idea was to allow the students to practice their abilities to communicate, which to designers is an important part of the presentation portfolio.

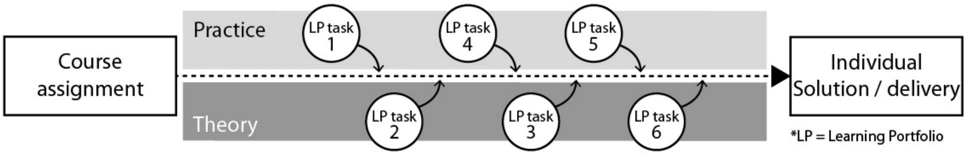


*Figure 1. Practical and theoretical exercises added content to the course assignment*

The learning portfolios were the objects of attention at the supervision workshops were the students worked independently. It was up to the students to choose an object for analysis and what models and methods they wanted to work with.

In a course evaluated through passed/not passed criteria, students tend to aim at lowest effort possible to pass in contrast to a course with graded evaluation. The purpose of introducing learning portfolios was therefore also to be able to gauge to what extent the students worked actively with all the theories, methods and tools from the curriculum. The learning portfolio thereby acted as a basis for evaluating the level of activity and whether or not the student take on an experimental approach to the tools, but not the quality of the solution or the graphical work.

In the experiment, the *presentation* portfolio included an unassisted, individual mini project with the theories, methods and tools used in the *learning* portfolio. During a common idea and concept presentation seminar the students received feedback on their presentation portfolios, which consisted of four sheets of A3. An external consultant from a collaborating company participated in the concept presentation seminars, and after the seminars, the students edited their respective presentation portfolios based on the feedback and their experiences from working with the learning portfolio. Finally, the portfolios were handed in for internal evaluation by the supervisor.

### 2.1 Consequences of Introducing Learning Portfolios in a Course Programme

The course programme "Experiment and Process" has been conducted both with and without learning portfolios. On the basis of this, the effects of learning portfolios are evaluated in relation to learning/level of activity, ability to individually develop mini projects, and lastly the level of communication. The course programme *with* learning portfolios was evaluated based on these,

whereas the course programme conducted *without* learning portfolios was evaluated based on A1 posters – a format known to the students from earlier study activities.
It was observed that the level of activity increased considerably during the workshops and the exercises helped clarify most questions. Furthermore were the exercises completed regardless of the duration of the workshops. The ability to complete the mini projects was the same in both courses, and the same was the case in relation to the covering of the technical aspects of the projects. However, the development of form and the level of communication were lower or the same at best in the course programme *with* learning portfolios. Working on the learning portfolio clearly made the students focus on theories, methods and tools rather than the other aspects. The portfolio method resulted in all students learning to use CAD modelling as part of the communication, which was a contrast to the earlier course programme.
The conclusion of the experiment is that the portfolio method based on learning portfolios with specific templates emphasise the learning goals and support the learning, but that the general competencies in communicating does not improve. This may be due to the implementation of the learning portfolio as some sort of draft or exercise. The reason for the presentation portfolios not improving the students' communication skills may be found in the general terms of the educational setup. Inclusion of portfolios should support the ability to learn through increased self-knowledge and insights about one's own weaknesses [3], but instead this is based on experience or inspiration from others. The reason for this lack of experience may be found in the admission requirements, which for this education is based on grades alone. This stands as a contrast to admission requirements for educations within the field of arts and craft, which often require a presentation portfolio. The industrial design engineering education in focus in this investigation has no tradition for the use of portfolios and only few of the students know the concept from elsewhere.

### 2.2 The Portfolio Method in Relation to Semester Projects

The semester project "Mechatronics and Design" on the 3rd bachelor semester was the students' first encounter with portfolios and comprises the second part of the investigation. In this case, the portfolios were uses as in the original Latin meaning of the word: *"portare"* (to carry) and *"folium"* (leaf). More specifically, the leaves were sheets of A3 with content that was pre-structured by the phases in the design process: observation/analysis, idea generation, concept development, detailing and product presentation. The aim was to maintain the student's focus on the design process rather than on written material for the traditional project report. This specific way of prioritising the resources also meant that the students got less time for incorporating the feedback from the status seminars. The term *work portfolio* is in the design profession also known as project folder: on-going documentation of the production throughout the design process [3]. The term project portfolio refers to the essence of the produced material in a project. In other words: a collection of sheets that – together with physical mock-ups – form the basis for the feedback at the status seminars. Together with the product presentation, the project portfolio constituted what could be coined as an evaluation portfolio.

### 2.3 Consequences of Introducing Portfolios in team-based projects

*The evaluation portfolio has the summative evaluation as its main purpose, where portfolio tasks are primarily included based on what is sought evaluated. (The student's freedom of choice may be limited, as the choice may have to be decided on the basis of what is possible to compare at an evaluation)* [1]. Due to this, the freedom of choice primarily lies in the selection of project vision for the student group.
During the oral examinations, the project portfolio caused some confusion to the examiner as some of the project portfolios included parts of research and ideas that did not relate to the product presentation. At the same time, some of the parts that the final proposals were based on were not included in the portfolios. It was thereby observed that the students did not reflect sufficiently upon the relevance of the content, or they did not have sufficient time for re-designing the project portfolio to support the design process for the product they ended up with. The goal of getting the students to focus on the process rather than production of a written report had been reached, but the project portfolios were at the same time more sporadically structured communication-wise, and the experiment did not improve the quality or level of their visual-communicative language.

### 2.4 Evaluation of the Portfolio Experiments

If we look at the initial intentions for integrating the portfolio method in the design engineering education, we are now able to recognise that some has been reached whereas other have not. The aims of putting a focus on certain learning goals and of increasing the level of activity have been realised. However, the objective of training the students' ability to communicate precisely through visual material has not had any effect. A comparison with traditional design educations in the field of arts and craft may show that the explanation is to be found in the lack of a portfolio tradition at the investigated education. The younger students do not have sufficient opportunities to benchmark their own communication skills against the work of older students.

A portfolio method that builds on the learning portfolio, and that includes templates related to the learning goals, should also include some guidance for assisting the students in developing a visual-communicative language. The book *Portfolio Skills* by Kevin Henry [4] was used as a reference during the interviews about design managers' recommendations to presentation portfolios. It would be obvious to use this or similar books as a "mirror" in the portfolio implementation phase. Design manager Bo Lindemann [5] pointed out that it is important that the students develop their own personal style. Lindemann receives presentation portfolios from international students, and according to him, these are often so generic that it is impossible to decipher the personal style and identity of the applicant.

## 3 THE PORTFOLIO METHOD IN INDUSTRIAL DESIGN EDUCATIONS

With this paper, we have put focus on design offices' recommendations for portfolios with the purpose of identifying the pieces in a portfolio method for the industrial design engineering education. The portfolio method must – as the design managers also point out – emphasise the visualisation of technical competences, illustrate skills in simulation and model testing, exemplify communication through storyboards and illustrate cases of product development, and lastly it should express the personal identity of the applicant. A strong visual-communicative language rich of information is key whereas short, precise sentences only acts as a supplement when the visuals come short.

This may be a portfolio method that builds on radically different pieces that the ones mentioned in the book "The Portfolio in a learning- and education-perspective" [2]. On the other hand, the portfolio method seems so open that the "language" is not decisive, when just the pieces are consistent with Lauvås and Jacobsen's list of what characterises the diversity of portfolios in higher education. These are [6]:

1. *The characteristics of the professional domain*
2. *Preconditions of the students*
3. *Objective and aim of the education*
4. *The broadness of the competence that is needed, together with interests, fantasy and ambitions from the creator.*

Communication through a visual-communicative language is a characteristic of the design profession that distinguishes it from the humanities just as the professional content.

### 3.1 A Template for the Portfolio Method versus Personal Learning Goals

For the younger students, the immediate goals are often primarily to achieve high grades. During the course of the education, the students start to reflect upon their learning in relation to their future profession, and company visits, lectures by external designers, and meetings with earlier students all add to a clearer picture of the profession. As the portfolio method focuses on the personal learning, it may be undesirable that the pre-structured templates, used in the two investigated cases, do not give much room for personal preferences. Using a visual language also means that the student's reflections first and foremost have to be deciphered through the content of the sheets and through the student's choice of motives, illustrations and layout.

According to the portfolio method mentioned by Lund [1],[2], students should write down their own personal learning goals in the beginning of a course programme, and these should be included in the criteria for the evaluation. The education in this investigation has not prioritised the development of individual learning goals as it may be the case in some art schools. Instead the education in focus here has chosen to implement specific learning goals for each of the many study activities. Personal learning goals could in this case be replaced by a common agreement on evaluation criteria for graphics, layout and the visual-communicative language by letting the students contribute with examples that illustrate good communication.

## 4 THE DIDACTIC GOALS OF THE PORTFOLIO

In general, Pettersen's model on change strategies in teaching covers the learning strategy for the course programme "experiment and process". The three levels of the model by Pettersen [7], [8] is shown in figure 2 below. Whereas the model shows the level of professionalism of the teacher, the three levels can also in a similar way be seen as a measure of the student's ability to learn and reflect:

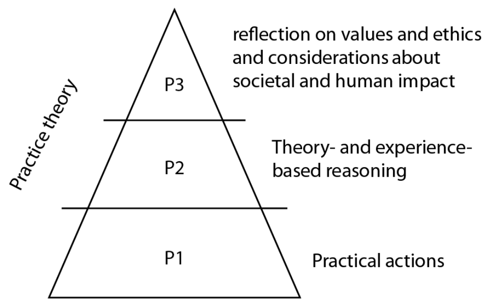


*Figure 2. The didactic pyramid of practice [8]*

During the course programme "Experiment and process", the aim was to facilitate learning on all three levels. Four of the lectures in the course focused on parametric construction in CAD. The learning activities in these lectures revolved around an approach that included simple tutorial-based instructions in the software. This trained the students' *technical skills* and facilitated learning on a practical level (P1).

The second level (P2) relating theory- and experience-based reasoning is utilised during course activities on project programming, semiotic analysis, and development of form as well as during ethic reflection. The students go through a practical testing of the theory and methods presented in the course.

The third level (P3) relating to reflection on values, ethics, and considerations about societal and human impact was brought into play in the individual part of the course. The students should engage in ethical reflections and bring the appropriate knowledge and methods into the course.

The portfolios should reflect the learning of all three levels and the students got feedback from a professional within the field of practice on which the projects revolved.

## 5 INPUTS TO APPLICATION-ORIENTED PRESENTATION PORTFOLIOS

Besides the attempt to increase the learning outcome of the course, the learning portfolios were also brought into play in order to prepare students to the portfolio format as it is typically part of job and internship applications. The design manager Thomas Harrit [9] recommends the students to choose a layout for their presentation portfolio that will work as independent sheets, each presenting specific competences. With a portfolio of 10-15 sheets, it should then be possible to convince a potential employer that the applicant possesses the qualifications that match the company's needs. The real question is, then, whether or not the work with learning portfolios, project portfolios and presentation portfolios during the education will help the student to realise what specific competences he or she possesses, and how the competences can be documented in the portfolio. During the visits to design offices, it became clear that design managers struggle with many almost identical portfolios from applicants. The individual presentation portfolios developed during the various course programmes could in principle be used even though the have been made in order to document fulfilment of certain learning goals and may not present specific competences.

The design manager Peter Møller-Jensen [10] emphasised the importance of design engineers being able to communicate through sketches during discussions with collaborators. Learning portfolios could in this case be used as a focussed tool for developing a strong visual-communicative language, which would be critical in this regard. Finally, the project portfolio is the ideal format for collecting material that will document and illustrate a case on product development. The company of design manager Jacob Brahe-Pedersen [11] uses this as part of their practice.

## 6 CONCLUSIONS

This research project has been exploring the role of learning- and presentation portfolios in design education. A case on a specific course programme has been investigated and interviews with design managers from practices have been carried out. It has become clear that, even though there is no strong tradition for learning portfolios in some engineering design educations, the portfolio method share some characteristics with presentation portfolios well known within the design practice. During this project, it has become clear that learning portfolios have a strong potential when it comes to directing the students towards the desired learning goals as long as this is clearly supported by explicit instructions and templates. However, it also became clear that most students in the investigated case were in lack of a sufficient visual-communicative language that would enable them to reach the full potential of the portfolio method.

During this research project it has also become clear that learning portfolios may serve an important purpose when it comes to creating personal content for a future job application. Design managers in a series of companies emphasise this aspect.

This research paper aims at initiating a discussion about how learning- and presentation portfolios can be efficiently implemented in design engineering educations that may not have the same traditions of portfolio-building as traditional arts and craft schools. The case investigated here shows that the method has a strong potential and is able to carefully direct students towards fulfilment of highly specific learning goals.

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# DESIGN PEDAGOGY AND THE THRESHOLD OF UNCERTAINTY

**Michael TOVEY and Jane OSMOND**
Coventry University

**ABSTRACT**
There is a long tradition of teaching design through design practice in universities and colleges. The end goal for graduates is to achieve a level of capability to function as designers in the professional world. Their education helps them create a passport to enter this community of professional practice. Part of the legacy of the funding initiative in England to support research into teaching has been the development of a better understanding of a practice based approach to design pedagogy. In two centres, signature pedagogies were identified as a distinguishing characteristic for developing student capability within varieties of design practice, focusing on those elements which are characteristic of the discipline. The emphasis moves away from the content of the curriculum and towards practical, embodied and experiential ways of knowing. For product and automotive design the concept of transformative practice was identified as crucial. Designers employ two simultaneous interacting cognitive styles. From a longitudinal study it became clear that in order to develop the confidence to match these two modes of thought, neophyte designers needed to surmount a barrier, which was labelled the threshold of uncertainty. Accommodating effective arrangements to accomplish this has reinforced the importance of employing the traditional arrangement of studio teaching.

*Keywords: Communities of practice, CETLs, threshold concepts, luminal spaces*

## 1 INTRODUCTION

Typically design education is based on what professional designers do, mimicking their practice. There is a greater emphasis on being able to accomplish the process of designing than being a repository of specialist knowledge. Students engage in design exercises of developing complexity which mimic professional practice. In the long tradition of teaching design in this way in our universities and colleges, the end goal is that of achieving a level of capability to function as designers in the professional world. Graduates wish to become part of the community of design practitioners and their education is the system they negotiate to enable them construct a 'passport' to enter this community. [1] Their design portfolio could be seen as their passport to design practice, in which they demonstrate that they can tackle design problems to a standard which is recognisably that of their professional community. They need to show that they can think in a 'designerly' way, engaging in a 'solutioning' process. Ability in creative synthesis is probably the most important ingredient in the mix which is required to achieve this passport.

## 2 COMMUNITIES OF PRACTICE

Across the wide spectrum of design practice there are many types of designers. Each could be considered as a separate professional community of practice. Typically a community is a group of professionally qualified people in the same discipline. Members will negotiate with and participate in a mutually understood discourse which is both explicit and, very often tacit. The signs of membership are usually clear and recognizable. The Community of Practice Theory devised by Jean Lave and Etienne Wenger [2] offers a way of understanding such groups. As a social theory of learning it highlights the value of our 'lived experience of participation in the world' [3] Within a community of practice, learning is an experience of identity formation. The accumulation of skills and information augments a process of becoming, and in the case of design this means becoming a particular kind of creative and critically minded design practitioner. Wenger call this "transformative practice", and within design practice that can become a source of motivation, meaningfulness and personal and social energy. Each group of designers represents a significant group of professional practitioners. We could include architects, industrial designers, design engineers, graphic designers, interaction designers, fashion designers, interior designers, craft designers, furniture designers, jewellery designers and many more.

## 3 THE CENTRES OF EXCELLENCE FOR TEACHING AND LEARNING

Between 2005 and 2010 there was major funding for the development of teaching and learning in universities in England. For the Higher Education Funding Council for England, the Centres for Excellence in Teaching and Learning (CETL) initiative was its largest single funding for pedagogy. Its aims were to reward excellent teaching practice, and invest in that practice. The CETLs were expected to provide substantial benefits to students, teachers and institutions. [4] 74 centres were funded across a range of universities, with a huge variety of types of pedagogic research and development across all discipline areas, and much of it interdisciplinary and collaborative. Communities of Practice figured quite significantly within their range of activities, particularly in the area of professional development. A CoP was defined as 'a group of people coming together from different disciplines or within a discipline for a common interest'. Sometimes these were formally organized within a discipline, and sometimes cross faculty, and they showed the widespread currency of the notion within the initiative.

17 of the 74 funded centres, touched on 'creative arts and design' and may have been working in areas directly relevant to design pedagogy. A much smaller number of centres had a direct location in design schools, and two of them covered work which focused directly on the development of practice based education as a preparation for entry to the design profession. They were the Creative Learning in Practice (CLIP) CETL at the University of the Arts London, and the Centre of Excellence for Product and Automotive Design (CEPAD) CETL at Coventry University

## 4 DEVELOPMENTS OUT OF CLIP AND CEPAD

As CLIP was based in the University of the Arts in London, it had access to a wide range of art and design disciplines across the federation of specialist colleges within the university. It was particularly well located to investigate disciplinary difference [5] and researchers were able to investigate the differences between Fine Art, Graphic Design, Fashion Product Design and Design for Performance identifying distinctive characteristics, and the spaces in which they occurred. The conclusions in this study included the importance of social approaches to teaching and assessment. It was possible to identify the signature pedagogies for particular groups which are common to such activities [6] developing in students the characteristic ways of thinking, being and acting in the discipline. There was a particular focus on the development of the community of student practice as an approach to student learning support within the course of study. [6] The key to accommodating students from a diverse background lay in more inclusive participation in learning activities where students are encouraged to undertake responsibilities with the tutors acting as facilitators or guides, emphasising partnership and collaboration over traditional didactic approaches.

Based in Art and Design, Coventry University's Centre of Excellence for Product and Automotive Design (CEPAD) has close links with the design profession, especially in transport. This has enabled it to develop what could be considered as the signature pedagogies for automotive design and product designers. They assume that in order to function effectively as designers they must engage in a designerly way of knowing. This is seen as a core capability which is shared across different types of designer. The intention could be seen as one of combining the generic designerly thinking with the domain related specialised knowledge of a signature pedagogy, to produce a level of overall capability sufficient to gain entry to the community of design practice. Cross characterizes design as an activity involving tackling 'ill-defined' problems through a 'solution-led' problem-solving approach. [7] The designer's attention oscillates between the problem and its solution, in an appositional search for a matching problem-solution pair, rather than a propositional argument from problem to solution. It would seem that the two processing modes are typically employed at the same time and interactively, and that a more complete understanding of any particular problem arises from the matching of initially separate simultaneous mental operations. The 'dual processing' strategy employed by designers involves a 'conversation' taking place between these two modes. [8] The result of this 'conversation', in what Tovey describes as an 'incubation period', enables a designer to arrive at a 'solution'. [9] This use of a blend of different thinking styles makes it difficult for many people to understand design. But to designers, these thinking styles are so intimately connected in a design project that they seem almost merged into one way of thinking. When steeped deeply in your design activity you just keep switching between analysis and creativity, between 'problem' and 'solution' without any effort. As Lawson and Dorst note,[10] 'in practice it is often devilishly hard to distinguish between them.' The evidence from the centre's research was that for neophyte design students being able to arrive at this match and thus a solution was a threshold capability. However achieving capability is such a solutioning process involved surmounting a key barrier, which was labelled the threshold of design uncertainty.

## 5 THRESHOLD CONCEPTS

The threshold concept framework was first introduced by Meyer and Land in 2003. It was used in CEPAD as a research framework to interview six industrial design students twice per study year from entry in 2005, to graduation in 2010. Qualitative data was gathered from UG and PG industrial design students throughout the longitudinal study, with a total of eighty-nine students taking part in the research. The threshold concept theory posits that there are crucial transformations that take place as students progress through their studies, which relate to both specific learning events within the curriculum and also to identity transformations. Thus, grasping a threshold concept transforms a student's worldview, and equips them to move onto the next stage of their learning. Meyer and Land refer to threshold concepts as 'portals' that enable a focus on the learning episodes which facilitate understanding of transformative concepts. [11] As outlined earlier, a threshold concept was identified and is defined thus:

> *'as akin to a portal, opening up a new and previously inaccessible way of thinking about something. [It] represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. As a consequence of comprehending a threshold concept there may thus be a transformed internal view of subject matter, subject landscape, or even world view.' [12]*

Additionally, Meyer and Land posit that threshold concepts include characteristics such as irreversibility (impossible to forget), integration (conceptual leaps within/outside discipline fields), and troublesomeness (resistance). This resistance often takes the form of previous knowledge, which can act as a barrier to acceptance. Such knowledges include *ritual* (intuitive) understanding; *inert* (stand-alone) knowledge; *conceptually* difficult knowledge – that which, if not grasped, can result in mimicry; *alien* (counter-intuitive) knowledge, and *tacit* (unseen) knowledge – often the background knowledge that informs particular disciplines or subject areas. [13] Because of these challenges, grasping threshold concepts can be uncomfortable for students, and result in unsafe conceptual spaces. Successful negotiation of these is dependent on a number of factors, such as student knowledge of the discipline 'game' before entry, confidence in deciphering the game once entered and ability to inculcate learning curves in order to move towards the next gateway. These spaces are referred to as 'liminal' (Cf variation theory), and Meyer and Land discuss four separate stages that students need to negotiate. [11] The sub-liminal stage concerns existing knowledge of the 'game' or episteme [13] which will vary according to previous educational background. The pre-liminal stage concerns the variation in how confidently students approach the threshold concept portal. The third stage concerns when they enter the portal itself – there will be variations they cope with suspension within an unsafe space, and whether or not they can pass through it. The post-liminal stage concerns the types of conceptual variations which are present in the students and how these relate to their progression.

For Meyer and Land, threshold concepts ( 'jewels in the curriculum') can help to inform course design by providing diagnostic points, and thus are 'literally…the waypoints to be navigated…they are what really matters in the course and where the key transformations educators wish to bring about take place.' [14]

## 6 LIMINAL SPACES

The liminal spaces identified by Meyer and Land within the threshold concept theory, can also be found within the creativity literature, [15-18]. Further, they are also acknowledged in the design literature. [19-22]. In particular, Tovey's notion of a dual processing/incubation period, and Wallace's problem bubbles have resonance.

In terms of professional designers, Daly *et al's* work on the different lenses that designers use when approaching a brief includes 'freedom', 'which allows for facilitated ambiguity and limitless possibilities from beginning to end of the design task.' [23] To reach this stage, designers need to pass through several others, much in the same way that Maslow posited in the Hierarchy of Needs theory.

[24]. As such Daly et al's stages can be compared to Maslow's theory in that lower level (basic) needs must be satisfied before progressing to the next level, with the ultimate aim of self-actualisation. In essence, designers begin with 'evidence-based decision-making', move towards 'organised translation, 'personal synthesis', 'intentional progression, 'directed creative exploration', and finally 'freedom'. Daly *et al* do argue that designers do not *have to* pass through previous levels in order to reach the 'freedom' stage: it is more likely that professional designers approach a task from one or more of the lenses, depending on their level of experience/preference. But it could be argued that this is the preferred aim of design teaching in higher education.

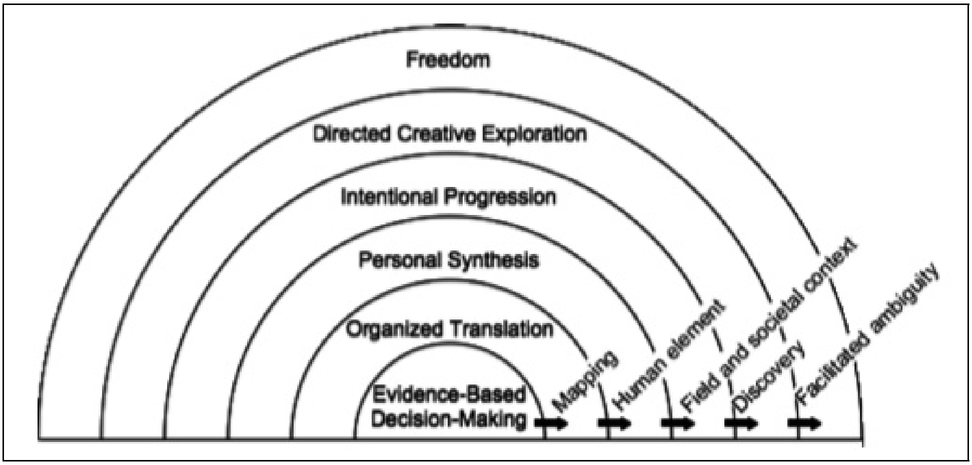


Figure 1. Outcome Space in Hierarchical Form [23]

## 7 LIMINAL SPACES AND THE ID CURRICULUM

Returning to the threshold concept research within the ID curriculum at Coventry University, as stated earlier, a threshold concept inculcating a liminal space was identified. **The toleration of design uncertainty** is defined as:

> *'…the moment when a student recognises that the uncertainty present when approaching a design brief is an essential, but at the same time routine, part of the design process.' [25]*

This threshold concept concurs with several of the characteristics outlined by Meyer and Land, namely that the acceptance of uncertainty is a prerequisite for the process of design, and so can be transformative and irreversible. It is also integrative, in that when students realise that by being uncertain and having to explore lots of different options, everything is a source of inspiration, not just what they learn within the studio. However, again in concurrence with Meyer and Land's characteristics, this realisation is troublesome, as it means that the students have to let go of the notion of a prescribed route to solutions.

This threshold concept also echoes Meyer and Land's liminal variation states, in particular the sub-liminal stage. In this case, there was evidence that previous educational experiences had fostered a 'what do we need to do to pass' mentality, which is at odds with the creative curriculum requirements within higher education (not understanding the 'game'). This, in turn, affects the pre-liminal stage – the confidence in approaching the threshold concept portal, which requires a free expression of creative instincts. Consequently, some students get stuck when presented with a brief that allows them the freedom to explore and so they can remain suspended within a liminal stage while they search for understanding. How they manage this liminal stage will therefore dictate how they emerge (post-liminal) from it – if they have not accepted the uncertainty, they will return again and again to the liminal state. If they have accepted it, they will also return again and again to the liminal state, but with the confidence to negotiate it successfully.

This is echoed by an Coventry University industrial design tutor, when he points out that students may either rush at a brief or, conversely, worry about marks and so restrain their creativity. Either way, the students do not have the experience to underpin their work, particularly in terms of whether the design is feasible. This can leave them in a liminal space where they are uncertain of their approach.[25].

The context for addressing this issue was the design studio. It is the arena in which there is the opportunity to achieve the integration of ideas which is at the core of design synthesis [10]. It is also the place where students can mimic professional design activity. The ID curriculum was redesigned in order to scaffold the liminal space with robust support – namely by introducing a quadruple module with a rising scale of marks. And so, the first assignment attracted only 10% of the mark, which allowed students to experiment and, if necessary, fail. The next assignment attracted only 15%, and again the possibility of failure was allowed, as the final mark was 75% which meant that the students could experiment, succeed or fail, but most importantly build their confidence in approaching the final assignment, free from the knowledge that the first two marks would ultimately affect their final grade.

In summary, the concept of Meyer and Land's liminal spaces are well represented within both the creativity and design literature, and a particular liminal space relating to design uncertainty was identified within the early years of the industrial design course at Coventry University.

## 8 CONCLUSIONS

In two universities in England the initiative to support pedagogic research has produced developments which help us to understand better certain key ingredients of practice based education. A key theme has been the engagement with communities of practice. The groups of professional design practice have a particular relationship with design education which manifests itself as identifiable signature pedagogies. For industrial design students a key feature of their education involves confronting a threshold barrier which we have labelled the toleration of design uncertainty. In approaching this threshold they are entering a luminal space which is typical in creative disciplines. For design tutors who are organizing courses there is a need for arrangements which allow both a safe arena and exploratory time in which this barrier can be surmounted. Traditional design studio teaching can be organized and assessments arrangements modified so as to encourage experimentation and the development of confidence in design solutioning.

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# EXPLORE, ADAPT AND REFLECT: EDUCATING DESIGN STUDENTS IN TRANSLATING DESIGN SUPPORTING TECHNIQUES ACROSS DOMAINS

**Jos Thalen[1], Mascha van der Voort[1] and Julia Garde[1]**
[1]Department of Design, Production and Management, University of Twente, Enschede, the Netherlands

## ABSTRACT
The interdisciplinary nature of design requires designers to be able to recognise potentially interesting emerging design techniques from neighbouring disciplines, such as marketing, management or engineering. A potentially interesting technique should be assessed, and, when found applicably, modified to suit a particular application in the design process. Training this skill to design students can be challenging. Students lack experience that designers use to make such assessments and modifications. This paper presents the results of a study in which we introduced an emerging design technique, LSP (Lego Serious Play) to graduate design students. The technique is introduced through a lecture and a workshop, after which the students are asked to assess its applicability in the product design domain by writing an essay. Students who expected LSP to be a useful design technique, attempted to apply LSP in a design case. By analysing the essays we aimed to find out how students assess new techniques, and how well they do this. It was found that in their essays, students present a relatively superficial review of the technique, touching only the obvious benefits and drawbacks. In order to fully understand (and in the end appreciate) the core values of the new technique, a regular lecture and a workshop turned out to be insufficient.

*Keywords: Emerging design techniques, teaching, Lego Serious Play*

## 1 INTRODUCTION
Design is an interdisciplinary profession. Consequently, design activities can benefit from input and support generated through techniques originally developed within other, adjacent disciplines. For example, many user centred design techniques used in the product design domain originate from software development disciplines. Designers should therefore have the capabilities to recognise potentially relevant techniques from 'foreign' disciplines, assess the applicability of the technique to product design, and, when needed, customise the technique to fit the anticipated design application. Training these skills to industrial design engineering students can be challenging. Although design students are generally expected to be sufficiently creative to customise a technique for specific applications, it requires experience and critical reflection skills to assess the applicability and relevance of a new design technique. This paper presents the results of a study in which students explore, reflect on and adapt a potentially relevant technique within their product development process. The primary aim of the study is to gain insights into how well design students are able to assess the quality and applicability of new design techniques. The secondary aim of the study is to gain insights into the applicability of LSP as a new design technique. The study was carried out with 37 graduate industrial design engineering students, who were first introduced to the LSP technique, and then asked to assess the technique in an essay. In a follow-up assignment, students who expected LSP to be a useful design technique, attempted to apply LSP in a design case.

The remainder of this paper is structured as follows. Section 2 further elaborates on the background of LSP to fully understand the technique that was introduced to the design students. Section 3 presents the approach and proceedings of our study. In section 4 we discuss the results regarding the primary and secondary research objectives.

## 2 BACKGROUND

LSP was originally developed in the mid 90's as an internal strategy development method by LEGO, eventually brought to the market in 2002 [1] [2]. The LSP method facilitates group discussions by letting participants express their knowledge, thoughts, issues, or opinions through LEGO models. The use of LEGO models ensures a balanced (i.e. everyone is equal) discussion in which every participant is able and facilitated to contribute (see [3] for an extensive overview of the working principles of LSP). The method is particularly useful for team building, problem solving and decision making.

It is expected that the method can also be deployed in a product development setting. It can help designers, or other stakeholders involved in the product development process, such as customers or suppliers, with discussing or elaborating on a specific problem, with reaching agreement on how to proceed, or with establishing a common ground between different disciplines. There are several examples of LSP being used in product design and engineering. [4] describes how LSP has been used successfully in design engineering classrooms for 4 years, *"encouraging full participation, creative contribution and communication across team members"* (p. 5). In [5], design students used LSP to facilitate workshops with stakeholders from the healthcare sector. Here the method primarily facilitated communication and interaction between the students and the external stakeholders rather than the communication and collaboration within the design team. Given the background of LSP and the successful application of the technique in several design and engineering settings, it is expected that LSP can be a useful addition to the range of techniques offered to design students.

## 3 APPROACH

The LSP technique was introduced to 37 graduate industrial design students in a course called SBPD (scenario based product design). The course introduces students to a wide variety of design methods and techniques, ranging from ethnographic research, body storming and personas to pivots, roleplaying and co-design. Each technique is introduced through a lecture combined with an assignment that students carry out in class. To investigate the adoption of LSP as one of these design techniques, three steps were carried out as further explained in the following subsections.

### 3.1 Experience LSP

The LSP introduction starts with a lecture briefly outlining the background and history of LSP, followed by an explanation of the working principles of this technique. The students then participate in a three hour LSP workshop. Because of time constraints, the workshop is reduced to a 'light' format, involving only the first 3 of 7 steps usually carried out in a LSP session (the full session was explained to the students in the lecture): 1) a warm-up build & storytelling assignment, 2) build and share the ideal coffee experience, and 3) build a shared model representing your group's ideal coffee experience. The design of an 'ideal coffee experience' was used as the topic for this particular workshop.

### 3.2 Reflect on LSP

After being introduced to LSP and having participated in a LSP workshop the students were asked to reflect on the technique by writing an essay. The essay should address why LSP could (not) be used as a design technique, what kind of participants would be involved, in which phase of the design process the technique could be used, and what kind of outcomes they expect from the technique.

### 3.3 Apply LSP

The students (in teams of 4) were then asked to develop a design approach for a specific design case. The design approach should make use of one or more of the techniques they had encountered in the course lectures. For each applied technique, the design team has to explain how, when and why the technique is used, and what modifications to the technique are required to suit their specific design case.

## 4 RESULTS

### 4.1 LSP Workshop

The workshop was facilitated by the authors, two of whom are licensed LSP facilitators. The workshop was recorded on video to review the proceedings afterwards. During the workshop we noticed that the majority of the students (both individually and when working in teams) initially had difficulty with working with metaphors and abstract models. Instead, they used the bricks to build actual products rather than representations of feelings, thoughts or emotions that usually facilitate storytelling. After making some remarks from the facilitators, most of the participants were able to eventually create abstract models and tell richer stories. Nevertheless, some of the final group results still contained a lot of 'concrete models' of products and settings. For example, rather than describing the 'ideal coffee experience' in terms of emotions or experiences, students modelled an entire living room and coffee machines.

### 4.2 Essay Assessment

After the LSP lecture and workshop, the student teams wrote an essay in which they assess the applicability of the technique for product design. The resulting 10 essays have been used to assess the students' ability to critically review a new design technique as well as its potential benefits for a design project. The essays have been analysed by labelling the sentences (or sub-sentences) according to an open coding scheme.

***Structure***

The first labelling round provides insights in the range of topics addressed in the essays, as well as the popularity of these topics (based on code frequency, see Figure 1) and the variety of topics within individual essays (see Figure 2). Overall, the essays primarily discuss expected benefits of LSP in product design, and the general working principles of the technique. This indicates that most of the design teams approached the essay assignment from the point of `describe why this technique works, and how', rather than `does this technique work, and why (not)?' Furthermore, most of the groups are also able to say something about the expected use of the application, and able to position the technique in a specific part of the product design process.

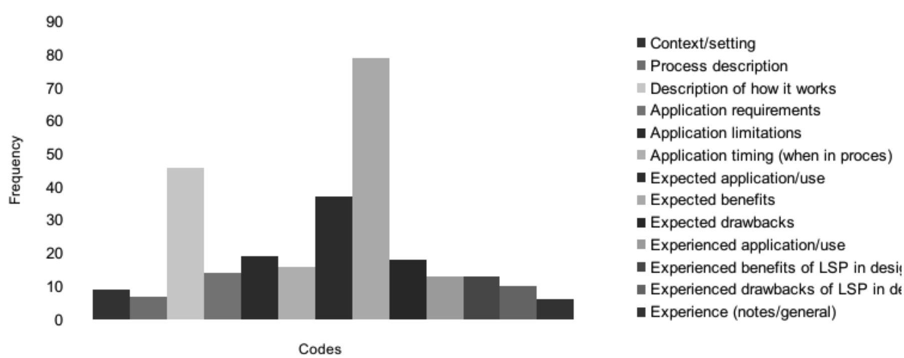


*Figure 1: Overall distribution of codes*

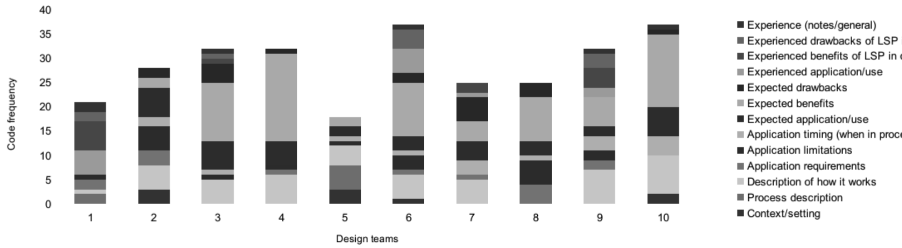


*Figure 2: Distribution of codes within essays*

***Content***

To further assess the quality of the essays, a second labelling round focussed on the content of each label. For example, \`expected benefits' may concern \`provide common language' or \`stimulate creativity'. The labels resulting from the first round have been re-examined and labelled into different content categories. The resulting content has been ranked according to their overall frequency (i.e. occurrence in the entire set of essays). To discuss the quality of the students' interpretation of the LSP technique, we will focus on the benefits and drawbacks described in the essays. Table 1 lists the content label frequencies of the 5 most frequent benefits and drawbacks and the 5 most frequent applications or use cases for LSP in the design process.

The content label frequencies show that most of the students expect the technique to be useful as an ideation and creativity technique that facilitates group collaboration and individual contribution. The benefits associated with this use are similar to those generally attributed to LSP. In particular, the *\`distance between user and idea'*, which refers to the safety that the models provide while storytelling is picked up well and appreciated by the students? The *\`low threshold'*, meaning that anyone can participate in the workshop, may not be the most relevant benefit of LSP, but the fact that the entire course was about actively involving end-users in the design process may have influenced the popularity of this benefit.

The drawbacks however also indicate that the students may have interpreted the LSP technique too much as a co-design technique, rather than a storytelling technique. In particular, drawbacks such as \`low level of detail' and 'predictable results' emerged from attempts to use the Lego bricks to build the actual product, rather than a model or metaphor to support a story (as also noted in section 4.1). For example, one essay mentioned *“The method is also not very suitable for designing a detailed physical representation of a product, since the participants are limited to the shapes of Lego parts”*. When considering the LSP technique as an ideation technique, the 'time consumption' drawback also makes sense as LSP is less efficient for this purpose than e.g. a brainstorming session; *“[...] it is very time consuming, and many results can also be achieved using other methods, like brainstorming”*.

*Table 1. Content label frequencies of the 5 most frequent benefits and drawbacks*

| Benefits | # | Drawbacks | # | Application/Use | # |
|---|---|---|---|---|---|
| low threshold | 13 | time consuming | 8 | stimulate creativity | 5 |
| distance between user and idea | 12 | low level of detail | 8 | individual contribution | 3 |
| stimulate creativity | 11 | predictable results | 4 | ideation | 3 |
| individual contribution | 10 | compromise | 4 | group collaboration | 3 |
| active participation | 7 | creativity block | 3 | discover hidden issues | 3 |

## 4.3 Design case

Of the 10 design teams (consisting of 3 to 4 students), one design team actually applied the LSP technique in their design case. One team mentioned LSP in their approach evaluation, saying *“[...] the CUTA session could be substituted by scenario based methods which emphasize more on emotional* *values, such as the LSP method"*. One other team mentioned LSP as a potentially useful technique, but refrained from using it because *"[...] the more experimental Lego Serious Play method would not have been worked, because the farmers take those things too literally"*. The other 7 teams did not explicitly mention the technique in their design report.

The design case in which LSP was applied concerned supporting the work (through product or service design) of people working in an animal shelter. The team's design approach involved an analysis phase in which the students aimed to gain insight in the daily work of the animal shelter employees. The team started with an ethnographic study (involving interviews, observations and working at the shelter), followed by a LSP workshop and a focus group. With the LSP workshop the design team aimed to gain a deep understanding of why the employees work at the animal shelter, and what they aim to achieve in terms of animal well being. In the subsequent focus group, the design team expects the employees to brainstorm about how they can change or improve their current way of working in order to achieve a higher level of animal well being.

#### *Session approach*

The LSP session took place at the animal shelter and involved six employees, including five volunteers and the manager. Two hours were available for the session, during which three tasks were given. Firstly, as a warm-up exercise participants were asked to describe what they like about working at the animal shelter. Subsequently, the participants were asked to describe 1) what a happy cat looks like, and 2) what a cat in this animal shelter looks like. In the final part of the workshop, participants had to combine the results of questions 1 and 2 to identify the similarities and differences between 'a happy cat' and 'a cat in this shelter'. In each step of the LSP workshop the participants build their model, present the model to the group, and have a short discussion about what (and, more importantly why) they built something. The session was facilitated by one of the design students, while the other team members assisted and observed.

#### *Session results*

Although it is not the main interest of this paper, the results of the LSP session are briefly summarised to give an indication of how well the session worked for this design case. The main factors affecting the difference between 'happy cats' and 'cats in the animal shelter' are 1) a lack of quality time between volunteers and animals, mostly because there are too many animals and not enough volunteers, 2) a lack of motivation among community service employees or trainees (i.e. non-voluntary employees) leading to a lack of attention for the animals, and 3) an uncertain future of the animal shelter because of constant financial and organisational changes.

#### *Students' Reflection*

In their design report the design team reviewed the application of the LSP technique. Overall the positioning of the technique was considered appropriate; the LSP workshop added a deeper level of understanding to the superficial results of the observations and interviews. With respect to the technique itself the design team encountered some initial hesitation among the participants to work with the Lego bricks. To overcome the hesitation, the facilitator joined the first 'warm-up' exercise to demonstrate how the Lego bricks can help with telling a story: *"[...] at first, it seemed a bit silly to them. [...] The participants overcame their hesitations very quickly and thought the LEGO was fun and rendered feelings of nostalgia"*. Eventually the participants engaged in the workshop and successfully constructed models and stories. The designers however noted that most of the participants found it difficult to work with abstract models and metaphors. Instead, participants often created a concrete representation of a particular situation. The design team attributes this to the level of education of (some of) the participants: *"It was concluded that the LSP method can be a very useful communication tool, but only for people with a medium to high level of education"*. Nevertheless, the design team considers the technique to be an effective means to actively involve participants in the analysis phase of a design project: *"This pleasant method of exploring the purpose of their work and their personal views opened the way to an equal and well balanced discussion. Pointing out the essence of their creation with a red stone and creating a common model with all essential parts together enhanced the idea of equal importance of every participant's opinion"*.

## 5 DISCUSSION

The results of our study show an interesting difference between how students assess a new design technique in an essay, and how they actually apply the technique in practice. The essays only contain a superficial description of the technique, its expected benefits and potential drawbacks. The students primarily try to prove the technique's added value to product design rather than assess its applicability. Based on the essays alone, our conclusion would therefore be that the introductory lecture and the LSP workshop were not sufficient to make the students understand the core values of LSP. Of course, it can be questioned whether the essays provide a reliable insight in the student's interpretation of the LSP technique. Firstly, time constraints within the course may have affected the quality of the essays negatively. The students may not have succeeded in properly capturing their perception of the technique in the essay. Secondly, the analysis of the surveys (i.e. coding the content of the essays) was carried out by one researcher. To increase the reliability of the analysis, a double review would have helped, or students could have been asked whether or not this is indeed how they interpreted the technique. Nevertheless, the superficial reflection of the LSP technique that results from the analysis corresponds to observations made during the workshop itself (facilitators had to point out the use of metaphors and abstract models). This leads us to believe that the surveys properly reflect the student's interpretations.

The secondary aim of the study was to gain insights into the applicability of LSP as a new design technique by evaluating the student's implementation of this technique in a practical design case. Based on the results of this study it is difficult to provide a clear answer to this question. On one hand, as already discussed the majority of the design students indicated that the use of LSP in a design case is limited. Furthermore, only one out of the 10 design teams decided to actually use the technique. On the other hand, the group that did use LSP in their design case was able to successfully deploy the technique after receiving additional guidance on how to implement the technique in their design case.

Letting students pick the techniques or methods they find useful may be a risky approach for design courses, unless you are sure that a technique is properly understood. The study has shown that we can not always assume a lecture and a workshop or demonstration of a new design technique to provide students with sufficient insights for a proper assessment. In this case, presenting students with a 'light version' of the LSP technique proved to be insufficient for them to fully understand and assess its applicability in a design case. Spending more time on explaining all the steps involved in the technique, and providing them with a more elaborate experience of a LSP workshop could have contributed to a better understanding of the technique.

## ACKNOWLEDGEMENT

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# FROM GESTALT TO EXPERIENCING – 2D/3D DESIGN FUNDAMENTALS EDUCATION IN DIFFERENT CONTEXTS

**Christian WÖLFEL[1] and Katja THORING[2,3]**
[1]Technische Universität Dresden, Germany
[2]Delft University of Technology, The Netherlands
[3]Anhalt University of Applied Sciences Dessau, Germany

**ABSTRACT**
Fundamentals of 2d/3d design have been taught since before (product) design curricula were developed in the early 20th century. Since then, design fundamentals education seems to have undergone major changes as design education in general. On the one hand, the theoretical and pedagogical basis of design fundamentals is based on traditional concepts, such as aesthetics, Gestalt psychology or the use of material.

On the other hand, concepts that have only recently become relevant for design are now also part of design fundamentals lectures: with regard to humans experiencing and interacting with products (product experience, UX etc.) tutorials in affordance theory ([7] and others) and narratives have been anchored besides traditional elements, such as aesthetics, proportions, and the like.

This paper outlines the historical roots and concurrent theoretical framework and provides selected examples of two different programs of design fundamentals. These are the relatively highly formalized and compressed design fundamentals in the specialization program of Industrial Design Engineering at Technische Universität Dresden as well as two- and three-dimensional design fundamentals in the slightly broader program of Integrated Design Studies at Anhalt University of Applied Sciences in Dessau.

*Keywords: Design fundamentals, aesthetic judgment, industrial design education*

## 1 INTRODUCTION

In Germany, design education – and thus education in design fundamentals – has its roots in applied arts schools, the Deutscher Werkbund, the Bauhaus and in the free arts. This is associated with a strong focus on the actual doing and experimenting with materials – today often associated with the "material-specific" workshops of the Bauhaus. One of its aims is to explore the design potential and also the limitations of the material and offer appropriate solutions. Historically, artistic, creative and perceptual fundamentals were established at many art schools, involving tutorials in color, 2d/3d shapes, sculpture and space (cf. [1] for a comprehensive overview of the development of design education in Germany). In addition, representation techniques (drawing, CAD, photography, etc.) play a significant role in design education as a basis for subsequent design projects. And at least since the Ulm School, methodological and scientific aspects of designing were increasingly anchored in the curricula of many universities.

Problem solving or developing innovative products and systems are moving more and more into the focus of design basic training. These developments raise the questions: which status does design fundamentals education have today and what role does aesthetics play. This paper aims to present two examples of quite different schools of design – the TU Dresden and the Anhalt University of Applied Sciences in Dessau – which offer historically rooted, yet contemporary design fundamentals.

## 2 THE DIVERSITY OF TEACHING DESIGN FUNDAMENTALS

Heinemann and Horning [6] described the objectives of the "design fundamentals education" (for their school) in 1983 as the communication of "knowledge of the most important laws of aesthetic perception of shapes and colours, [their] creative application [...] to endow students with the ability to judge." (transl.) Today the conception of design fundamentals is broader. Birgit Gurtner [4] states in her analysis of current concepts of design fundamentals education that a single definition or content description cannot be found, yet she outlines three basic approaches:

- "formal syntacticx [...] elementary 'school of seeing'; often rational, methodical; historical roots" (ibid., p 31, transl.)
- (drawing) education focused on nature and perspective
- conceptual and recipient-oriented design fundamentals, "often with social and artistic implications" (ibid., transl.).

The "more scientific approach" to design at the Ulm School of Design led to a stronger methodological underpinning of the design fundamentals [2]. As a consequence, design schools in both German states more or less continued this approach. As part of this development, for example the study of design methodology and Gestalt psychology have been included in the design fundamentals education. Since these psychological perception effects will probably always rate high, they remain relevant even today. In addition to traditional aesthetics, semiotics became an essential part of design fundamentals. Phenomena of semantic qualities and pragmatics of designed artefacts may also be explained by perceptual psychology – and have a high priority for the design fundamentals education. This is confirmed by the accomplished paradigmatic shift from static design objects to the interaction between humans and designed artefacts. Semantic evaluation (and semantic design) is needed to let humans experience the inherent properties of artefacts – though subjective (~ly designed) but general (in reception). Is this drill press powerful? Is this car fast? Such questions are strongly linked to the pragmatic meaning of artefacts. As meaning in the application context and the object's environment, pragmatics also include the concept of affordance ([3], among others): Sit on it! Turn me! Click here!

Syntax, semantics and pragmatics are treated both individually and in their interdependence in design fundamentals education. The communication between an artefact and its (potential) users is also a subject of cognitive ergonomics and usability. Semiotics, usability and affordances are closely connected and form the main content of design fundamentals education today.

Following the experience paradigm (Product Experience, User Experience etc.), designers are even more faced with the need to tell stories. Viewing product experience and product interaction as a process, designing always involves narrating. Accordingly, Norman [7] claims that the ability to develop stories is a prerequisite for designers. If this requirement is taken seriously, narration must be part of the design fundamentals education. In terms of didactics, this can be implemented by interpreting experience and narration as complex applications of semiotics – from signs to stories.

## 3 AESTHETICS AND JUDGMENT

Still, aesthetics is the basis of all design fundamentals, at least as an evaluation criterion.

Following the etymological origin of "aesthetics" as "perception" and "sensation" (aesthesis), aesthetics can be understood as the science of how people perceive artefacts (cf. "aesthetics" as empirical aesthetics research in terms of the measurement of the perception of "beauty").

In contrast to this, traditional (German) philosophy and sociology deal with aesthetics as a theory of beauty and art – but again there are different readings. In the particular context of design, Kant's "Critique of Judgment" and its "aesthetic judgment of taste" is important [6]. Here aesthetics refers to the beautiful and the sublime. Kant's description of aesthetic judgments as made subjectively but being generalizable (the claim of universality which is not to be confused with the findings of today's empirical aesthetics research that empirically measures the assessment of "beauty", i. e. quasi-objectively). This is an important prerequisite that allows designers to decide subjectively how the aesthetic dimension of artefacts may be generally assessed. According to Kant, a judgment of taste is disinterested, so it is not connected with any purpose. In this sense, many artefacts developed within the design fundamentals education are without purpose. Accordingly, any (positive) evaluation of an artefact has nothing to do with purpose (e. g., social or technical function). Nevertheless, artefacts should not simply be judged as "beautiful" or "ugly" – rather than that it should be evaluated how an artefact incorporates various sensory dimensions in order to define its aesthetic position.

## 4 DESIGN FUNDAMENTALS AT TU DRESDEN

At TU Dresden, the Industrial Design curriculum is placed in so-called advanced modules as a specialization within a modularized diploma course in mechanical engineering. Industrial Design shares its exotic status within the program and within the Faculty of Mechanical Engineering with other disciplines, such as ergonomics. Students of the Industrial Design program graduate with a degree in mechanical engineering (the degree Diplom-Ingenieur is regarded as the equivalent of the MSc or MEng), although nearly 100% of them later work as industrial designers in design divisions, design studios or as freelancers.

Högner developed his "basic training in visual-aesthetic designing" [8] at the art school in Berlin-Weißensee in the 1960s, his followers held on to this concept and established it at other design schools. Högner himself brought his approach to TU Dresden, initially as an additional qualification for engineers. Today, it is still the conceptual basis of the basic 2d/3d design training.

For organizational reasons, the major part of the design fundamentals education is carried out in the sixth and seventh semesters, after the extensive engineering and science courses (1st–4th semester) are completed. The short time frame of the remaining studies requires that the teaching of design and the theoretical foundations and the practical design projects overlap, at least partially. In this paper, the elementary fundamentals of 2d/3d design will be considered in more detail, because they are exemplary of the other design fundamentals courses.

The analysis and evaluation of shapes and artefacts is substantially based on concepts of semiotics, geometry as well as the aesthetic judgment of taste. While students at many design schools are confronted with aesthetics as a philosophical theory of perception or of art and design in theoretical courses, aesthetics is here reduced to a practical criterion. However, it is the central criterion in the design fundamentals and is taught as such, and the aesthetic judgment is developed forming an awareness of the aesthetic qualities of elementary design.

To address the tense interplay between the necessity to satisfy this criterion and to integrate the students' previous engineering education, a differentiated aesthetic assessment scheme was established. Students start applying it to shapes of low complexity (e. g., figure-ground contrast). As the students' design fundamentals education progresses, the complexity of shapes and objects increases, the assessment scheme is internalized and finally applied intuitively. Within the scheme, both objective "correctness" (e. g., via design rules or curve analysis) and subjective "appeal" (aesthetic judgment) are evaluated – initially explicitly and step-by-step, later on more fluently and intuitively. On the basis of this assessment, a particular change to the shape or object is defined and implemented. The result can then be re-assessed. Care is taken that the changes (e. g., angle, radius/curves) do not relate to too many properties at once. So on the one hand, their influence on the assessment can be better traced (and learned). On the other hand, the interdependence of different formal properties on each other can be recognized more explicitly, e. g., after strong rounds have been added to a designed shape, (previously) well-balanced angles must be re-optimized in order to obtain an aesthetically satisfactory result.

In the course of the semester, students work on increasingly complex tutorial problems of two- and three-dimensional design at the same time. Two-dimensional and three-dimensional tutorials complement each other in terms of content and are run in parallel. The tasks are built on content of upstream courses (as freehand drawing) and are continued and applied in later courses (such as the CAD modelling of aesthetic free-form geometry).

## 5 DESIGN FUNDAMENTALS AT HOCHSCHULE ANHALT IN DESSAU

The Department of Design at the Anhalt University of Applied Sciences in Dessau was founded in 1991. The seven-semester Bachelor program "Integrated Design" combines the classic design disciplines of product design, visual communication and time-based media. Following an interdisciplinary approach, all students accomplish all eight fundamental design subjects in their first year regardless of their (later) specialization. The design fundamental are certainly strongly influenced by the different backgrounds of the respective eight teachers, hence it can not be traced back to a single tradition. In this paper, the focus lies on the subject "2d/3d design fundamentals" which is a central element that links the fundamentals of product design with neighbouring disciplines. In the 3rd semester, orientation and elective modules are offered that increase the previously learned fundamentals and extend them experimentally before the students start to set their focus on visual communication, product design or time-based media in the 4th semester. The design fundamentals education in Dessau basically follows a classical approach incorporating various drawing techniques, material and technology studies and technology as well as artistic and design fundamentals.

Methodological approaches on designing aesthetical artefacts are primarily taught in “2d/3d design fundamentals” as presented in this paper.
Aesthetics play a central role in almost all tutorials of the design fundamentals in Dessau, they are accompanied by tutorials on perception and by developing sensitivity and an understanding of aesthetic shapes. Formal aesthetic studies and their analysis are part of the curriculum as well as tutorials on semiotics. The curriculum also includes tutorials that focus on the development of skills that allow students to analyze and evaluate existing design examples from an aesthetic point of view. At an advanced stage (beginning in the 3rd semester), narrative tutorials come into play. A particular focus lies on the ability to tell stories about their own designs or to encourage users to think. The concept of aesthetics is frequently used as evaluation criterion, however without a formal evaluation scheme as described above for TU Dresden.
Some of the tutorials are real ‘classics’ of design fundamentals, and were taught in one way or another at other schools decades ago. Others were developed at Anhalt University of Applied Sciences to respond to the specific requirements of integrated design studies in Dessau, or to embrace current design trends.

## 6 EXAMPLES OF BASIC DESIGN TUTORIALS

Many of the design fundamentals exercises at TU Dresden and Hochschule Anhalt aim at developing sensitivity and an understanding of aesthetic shapes, at designing material-adequate shapes and structures, and also at communicating semantic messages through form.
The design fundamentals education with its components is consistently aiming at producing aesthetic results (partly as a vital criterion of the task, partly as an implicit requirement). Below we discuss some of the practical 2d/3d basic design tasks offered at the two higher education institutions.
Early on during the design fundamentals education, students conduct a product analysis which is designed to exercise the (correct) use of (correct) terminology and also to offer access to understanding the aesthetics of elementary formal elements. At TU Dresden, the tutorial *Analysis* focuses on the semiotics of small consumer products. At Anhalt University of Applied Sciences, the analytical framework is broader: The tutorial on a blog about »bad« design – does not only teach students aesthetic and formal judgment of taste, it also aims to develop the students' ability to identify non-functional products, badly thought-out systems or ethically inappropriate designs. The analysis of the discussions shows that students independently and repeatedly refer to aesthetics as an evaluation criterion.
The tutorials *Paperlab* (Dessau) and *3d Freeform Interpretation* (TU Dresden) deal with the interpretation of a given object in a given material (paper or plaster) with the aim to make students sensitive for the aesthetic qualities of three-dimensional geometry and also for experiencing the handling of materials. These two skills are prerequisites for other tutorials and are further extended. Dealing with paper is subject of the basic tutorial *Package Arrangement* at TU Dresden and also as a possibility of rough prototyping in design workshops. The major content of the traditional design fundamentals exercises is taught in two-dimensional and three-dimensional semiotics of aesthetic forms (Figure 2). The semiotic categories are completed by pragmatics. The latter is part of a tutorial on designing the affordance character of simple objects. Students are required to develop a pragmatically refined design for given interaction forms for given volumes and – at the same time – to implement these forms aesthetically and using uniform design vocabulary (shared family identity). While working on a task, students will learn to understand the mutual influence of syntax, semantics and pragmatics of an object.
Narrative elements play an important role in the 2d/3d design foundation course in Dessau. For example, the tasks "Design Monster" and "Paper Portrait" aim to tell a story in a visual manner (Figure 4). In the exercise “Talking Objects” the task focuses on narration. The ability to tell stories through a design and thus to inform the recipient or user to entertain him/her, or to encourage a critical reflection on her/his own course of action, should be investigated. The result is a series of more or less ‘purposeless’, narrative objects that tell a poetic or ironic story.

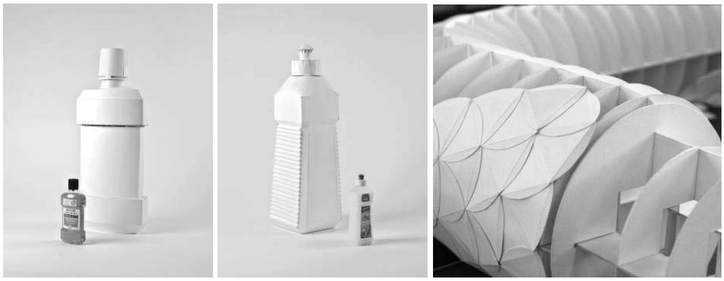

*Figure 1. Ttutorial »Paperlab« – reconstruction of everyday objects in paper, M 3:1, HS Anhalt left: Listerine by Kristin Sauer & Christian Schamari, centre: Fit liquid dishwasher by Aileen Wilke and Sascha v. Oettingen, right: paper construction – to the detail, 2011)*

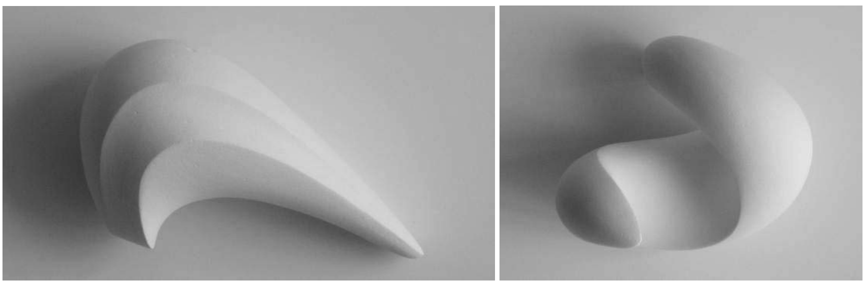

*Figure 2. Semantic freeform sculpture, TU Dresden (plaster of Paris, approximately 10 cm, left on the concept »powerful«, Janine Kasper 2012; right on the concept »sensitive«, Lisa-Marie Lüneburg 2012)*

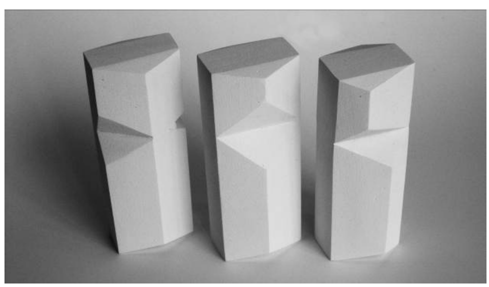

*Figure 3. Tutorial »Pragmatic Forms«, TU Dresden. (PU foam, from left: Bending, Pulling, Turning, Fanny Hauser 2012)*

*Figure 4. Tutorial »Design Monster« – Visualization of a Given Concept Using Paper and Orchestrated Photography, HS Anhalt (left: »Enthusiasm«, Frederik Dühsler, right: »Nostalgia«, Maximilian Fuchs, 2012).*


*Figure 5. »Talking Objects« – HS Anhalt, Time Telling Machine; Criticism of Everyday Stress (Design: Frederik Dühsler, 2013).*

## 7 DISCUSSION

This paper analyzes the design fundamentals education at two different German Universities, with the goal to identify new trends and focal points within design education. The two analyzed courses demonstrate a shift from traditional craft and aesthetic education, as it has been known in the past century, e.g. in the German Bauhaus, towards more current streams of experience design, problem solving, and design narration. A product can tell a story, the context defines the product experience, and students should learn to critically discuss a design. Although the traditional pillars of design education, such as form studies, material experiments, or construction exercises, are still relevant and play their part in the two analyzed institutions, emerging concepts like user-centered design, critical design, affordance, and narration, have become equally important in today's design fundamentals education.

Although the two analyzed design institutions represent only a narrow insight into today's' design education, we believe that the presented cases in this paper indicate a shift in design education that warrants further research, e. g. in other institutions. Furthermore, the presented examples of design exercises might inspire design educators to implement new forms of exercises that allow for a user-centered, experiential, or critical discussion among design students, starting already from the first year of their education.

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# PEDAGOGY: LEADING TECHNOLOGY

**Phillipa MARSH and Les ARTHUR**
Nottingham Trent University, UK

**ABSTRACT**
This paper is based upon a combined 40 years of experience the authors have in working with and teaching technology in Further and Higher Education. The relationship between students, technology and educators is a complex one which has a rich tradition to draw upon. The purpose of the research - inclusive of one small case study - was to identify the overarching purpose of the relationship and to highlight the good and to consider whether potential problems may arise if there is an over reliance on technology within the context of Design Practise. The relationship has been reflected upon from an historical and practical perspective. Many of the attributes, but not all, are considered that the Designer must possess to be employed or involved in research are referred to within the text. The current cultural reference points are defined to contextualise the influences that technology has today to the different age generations. An assessment of a small group of students' drawing ability highlights some of the problems that have been encountered in recent years in the process of understanding the cognitive operations enacted in the process of drawing. This paper proposes that a closer inspection of what has been understood; needs to be re-defined so that the relationship to technology, students and academics have a consensus of understanding which ensures that pedagogy leads technology.

*Keywords: Design reflection, technology, designer skills*

## 1 INTRODUCTION

The central focus of this paper is correlating the vested interests of students, technology and academics. The paper contains one small example of assessing ability and reactions to technology. The case study involved the act of drawing is an experiment to a mixed student cohort. It is asserted, that although supportive of technology the authors suggest that the key areas of: iteration, design, studying, the act of being reflective; plus the concept of hermeneutics and phenomenology is the ability to critique should not be diluted. There seems to be a common assumption that equates new technology to the value of good, but whether this is true in relation to the education of the designer needs to be questioned in terms of the quality of education and the everyday concern of resources and financial constraints that academics have to consider.

There is always going to be the perennial debate concerning want and need aspects of technology within a university by staff and students. Too often the premise is based upon 'it will make things better for all'. As a stop gap and an introduction to technology and training that may be so, however, that is not education. There seems to be a link between: assumed capitalist economics, the production of new goods and the perpetuation of material wealth, if this is so there is a concern whether the aesthetics from Tokyo to the Europe will be the same. Historical resonances and cultural differences may not be celebrated, but be subsumed by the production of 'goods that work only'. There is a debate to be developed which rises above the superficial and recognises other areas of knowledge and the relationship to people and technology ranging from the philosophical and the practical education of the designer.

The relationship between people and technology and design education is complex and one which needs to be understood from a number of different perspectives. One thing that separates us from technology is our ability – a crucial one – to contextualise and think independently about a leitmotif. The following variables are essential part of the toolbox a designer must have: the ability to reflect, to use this concept to teach, being aware of our personal cognitive processes and realising that pedagogy must lead technology [1]. Although there are many suggestions that technology will accommodate these skills in the future in the world of Artificial Intelligence. The 'what if' scenario within AI still needs to be resolved, people do not think in simple polarised ways. However, the development of fuzzy logic and neural networks suggest that research is aiming in this direction˙

By consensus many lecturers today seem to feel that under graduates are adequate to excellent in describing their work to academics in the studios or in a literary context. However, it is the area of being able to critique that seems to be the cause of many problems. If it is accepted that managing by objectives occurs at all levels of the curriculum. Subsequently, if this is acceptable as a generalisation it is unlikely that students would be comfortable producing critical discourse. Consequently, this increases the gap to technology as at the epicentre of technology is the binary system. Many academics would prefer an end product of research to present an empiricist approach that yields something tangible. This is solid evidence of a conversion of the abstract to the concrete. This is a process that is taught across many areas of design. Academics have worked with technology for many years, but there are at least three things that technology still struggles to accommodate, these are: the significance of emotions, ownership and the diverse range of processes used in the act of designing. Technology and the associated areas from software to robotics are sometimes defined in utopian terms and the assumption that technology will make everyone feel better; the converse argument to this is the dystopian view, popular in the counter culture of science fiction that which suggest that the point of singularity is on the way and the machines are taking over from people. The selling of technology traditionally referred to objects being labour saving devices. The middle ground between these points would seem to be the sensible, in terms of education, the use of technology and the maturing of our connection to technology seems to be realistic and responsible.

### 1.1 Case study

A final year undergraduate student at Nottingham Trent University [12] was convinced that his drawing was not of the standard which will be needed for him to gain employment. He could not obtain a drawing assessment a method could not be found that measured proficiency related to personal skills and what he perceived as a professional level needed to gain employment. He had to construct his own assessment system to measure whether he was informed enough to the level that he required. He designed a simple drawing test and a questionnaire that was given to under and post graduate students after they had been given a lecture on drawing. The results he obtained presented information that identified a number of areas in which the students were struggling. These same students had been working on successfully on CAD systems for several years. On screen they felt they understood three dimensions and had produced work of excellent quality, but struggled with the same concepts on paper.

## 2 RESULTS

The assessment was experimental in character and the aim- was to gather data that evaluate the level of drawing ability design undergraduates possess at different levels.

The objectives were:

- Design an experiment that will to assess the students' range of drawing ability
- To establish a variety of skills that a three-dimensional designer must possess through drawing
- Allow each test assessment to provide only one or two solutions.
- Design the assessments so that the majority can participate in order to gather as much data as possible.
- Garner feedback from the undergraduates.

There were a number of areas that raised concern from the pilot these existed in the following areas: Question 2 extrusion, Question 6 the oblique, Question 7 the scale factor 4 applied, Question 9 Rotate around 90 degree axis and Question 10 Select and covert into shapes into the oblique 2 views from a series of drawings.

The suggestion in Gale's work [12] presented 'areas of consistent weakness amongst (*the*) participants and as a result it has been possible to propose improvements to the content of education design and art undergraduates receive. The syllabus needs to include both more detailed lectures and tutorials on: geometry observational studies (*including the life room*) Technical drawing *(and*) Perspective'. He continues,' (*there was)* strong evidence and identified patterns in the results suggests that students were not confident in their theoretical or working knowledge of using traditional drawing techniques suggesting that there is a robust correlation between the perceived problem by the individual and the group in their lack of understanding concerning the space between fundamental knowledge and contemporary Design practise.' At the beginning of this research, which was overseen by the author, in discussions there seemed to be a consensus that expected the outcome, based upon the many comments from students over a substantial period of time.

Naturally, there has to be caution in interpreting the datum as it is a small number, but that does not negate the potential significance, this may suggest that there is a loss of knowledge which is fundamental, whether this is because historical information is not taught or people have become over reliant on technology is something that needs reflecting upon. There could be value in extending the research to a wider group on several levels within design education, particularly considering essential understanding at all levels within the curriculum.

The relationship to technology is informed in a number of ways from the scientific to the populist perspective exemplified in the wide range of topics inclusive of design today including: biomimetics, medical design and nanotechnology. The world of fashion and textile design also research extensively in technology for innovations to become part of our everyday clothing, so the omniscience of technology cannot be ignored. It does need to be recognised that people – in the main the younger generation- feel affiliated to technology in other domain of their lives including, Facebook and the act of Tweeting. This is an important part of their social lives. The relationship to technology in this context is one of networking and communication. People in design education are diverse in character and in their responses to technology. The evangelists and the luddites will not always agree and that can cause tension where constant development and progression is demanded to resolve problems and a causal connection to resolution is linked to technology and of course the costs. There is a need to allow young designers to explore ensuring that during the early stages of their careers they are encouraged and allowed to examine a wide ranging of options to appraise the process of evolving ideas. Many of the students have grown into a technical world and the area of visceral design is not as common to them as it may be to the more experienced academics.

The relationship between designers and technology is not an easy one to characterise. The role of technology and the industrial revolution should be considered during that period of time technology was written about by Marx concerning the fetishism of the commodity. Several authors suggest this transcends barriers to combine purpose and spontaneity in the process of work and Roland Barthes several years later [2], [3]. It is important to recognise that this historical context couches some of the debate and the relationship, whereas students desire a personalisation of the curriculum today. There is a danger that the proselytising approach to technology encourages the anonymity of the designer, something that design education does not often perpetuate. Indeed, there is often the cultivation of the individual.

It would be safe to assume that many designers feel a connection to their work, this may be visceral it could be linked to emotions or materials. But there is also a connection to their work in another way which is highlighted in the way designers think and work when designing. The closest parallel to thinking about design within the context of psychology is cognition which researches the processes of how we think and uses the metaphor of computing. The act of designing involves many different processes for the traditional to the contemporary [4], [5]. Whichever process is used, from the conservative to the radical, the one thing that does unify their action is the domain of reflection' which is a necessary part to designing [6]. Design is not a passive manifestation it is a form of critical analysis which uses a different criterion from the academic context but it fulfils the same function in that the process resolves problems or creates ideas.

Throughout the process of design we use various forms of memory as reference points. We acknowledge the importance of the principles of design leaving representation and recall using intelligence and learning [7]. Apart from these there are several other areas that we use when designing these are: Decision making and the area of serendipity and user-centred design is still essential to articulate accurately by technology, but so much design is based upon the characteristics that are demanded from a designers perspective. Within recent years SMART Design has become significant in medicine because of the relationship to bio-mimetics leading to numerous innovations and a new bridge between the subject and the process [8]. It is understandable that people get caught up in the buzz of technology and the excitement of the new, but there are those who are sceptical concerning new technology and anxious at the presentation of the image rather than one of substance. The potential to forget fundamental knowledge of a subject, the possible erosion of the individuality of the designer and the blurring of cultural barriers may lead to 'beige design' following on from the historical black box aesthetics and the suppression of localised design rather than considering a whole range of possibilities linked to design [9].

Conversley, a debate could be held that suggests efficiency aligned to shorter lead times and linked to manufacturing may reduce the cost for a product from cradle to grave and encourage more opportunities for the designer meaning shorter processes, work that can be global in seconds and greater openings for the freelance and self-contained designer. In addition, there are new makers of the industrial revolution [10]. The relationship to technology that designers have been requested to focus upon is a timely one for educators. Collectively, we are all aware of the significance of IQ, but, there is also the EQ to consider. Although, these are interesting areas to reflect upon are we now to expect the TQ (technical) or IQ (2) on innovation to become significant also.

## 3 CONCLUSION

This paper was written to advocate a proposed balance between the education and the training of the designer in Higher Education. Historically, there are references to those who are cautious and those who remain eager to use the technology that is available today. However, there is a relationship that needs to be sagacious in the use of Technology and an encouragement not to see it as a panacea for Design, but to facilitate the process. Within technology and design there are those who are almost addicted to being aware of developments and those who are reluctant to be engaged with the role of the new processes of design. The polarity negates and ignores the link between people plus technology and overstates an unworldly approach to contemporary developments. Whether we can predict the next 50 years in design is a moot point [11]. The relationship between people and technology will increase to some extent, whereas to some there may be fixity of their purpose towards technology. Technology has significantly contributed to design and engineering. The maturing of the knowledge and its relationship to people and the subject will continue to develop, nevertheless it is people that will enact the designing and will also endure in ensuring that pedagogy leads technology.

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# ECO-CAR: A PERFECT VEHICLE FOR TECHNICAL DESIGN TEACHING?

**Lyndon BUCK[1], Christian McLENING[2] and Jonathan BURGESS[2]**
[1]Buckinghamshire New University, UK
[2]Aston University, UK

**ABSTRACT**
Design methods and tools are generally best learned and developed experientially [1]. Finding appropriate vehicles for delivering these to students is becoming increasingly challenging, especially when considering only those that will enthuse, intrigue and inspire. This paper traces the development of different eco-car design and build projects which competed in the Shell Eco-Marathon. The cars provided opportunities for experiential learning through a formal learning cycle of CDIO (Conceive, Design, Implement, Operate) or the more traditional understand, explore, create, validate, with both teams developing a functional finished prototype. Lessons learned were applied through the design of a third and fourth eco-car using experimental techniques with bio-composites, combining the knowledge of fibre reinforced composite materials and adhesives with the plywood construction techniques of the two teams. The paper discusses the importance of applying materials and techniques to a real world problem. It will also explore how eco-car and comparing traditional materials and construction techniques with high tech composite materials is an ideal teaching, learning and assessment vehicle for technical design techniques.

*Keywords: CDIO, curriculum alignment, collaborative working, experiential learning*

## 1 INTRODUCTION

The Shell Eco-Marathon, now organised by Shell Global Solutions, dates from 1939 when Shell employees made a wager over who could travel furthest on the same amount of fuel [2]. Since then it has expanded to three continents, includes energy types ranging from biofuels to electricity, and sparks debate around the future of energy and mobility. Technical and practical skills developed through design and engineering undergraduate courses are applied to create ultra-energy efficient cars in the Shell eco marathon competition - with some reaching 10000mpg. It is an ideal learning vehicle around which students can showcase their analytical skills, engineering theory, design and materials knowledge by applying them to a sustainable design problem. A TLA strategy has been developed so that students can take full advantage of this project (Figure 1).

## 2 ECO-PRO

Eco-Pro was designed in 2010 by two Mechanical Engineering Design students using a traditional 'final year project' format - the culmination of taught theory, put into practice by completing an engineering challenge. Eco-Pro was entered into the energy efficient prototype category of the Shell eco marathon, as such, it was designed with a 23.5kg carbon fibre and paper honeycomb monocoque chassis, 35cc four stroke Honda engine and a weight of 42kg. It was developed using a 1/10 scale model through wind tunnel test and computational fluid dynamics (CFD) modeling, the $C_d$ of 0.16 at the top speed of $10ms^{-1}$. The vehicle achieved 900mpg in initial trials and then over 1000mpg when fitted with covers and a redesigned exhaust manifold. Fuel efficiency was achieved through a combination of CFD and FEA analysis, and lightweight materials. The strategy for reducing fuel consumption was to reduce the power required to propel the vehicle, through light weight, low friction and aerodynamics, and to produce the power more efficiently.

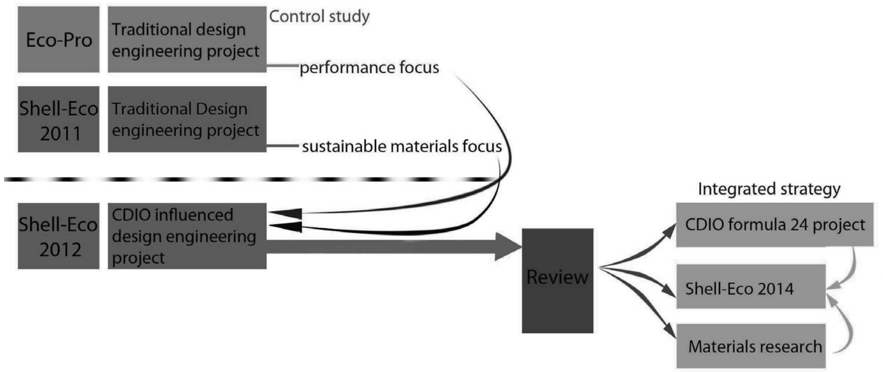


*Figure 1. Teaching and learning strategy proposed for the eco-car project*

*Figure 2. Establishment 1 - Eco-Pro (without covers, showing driver and engine)*

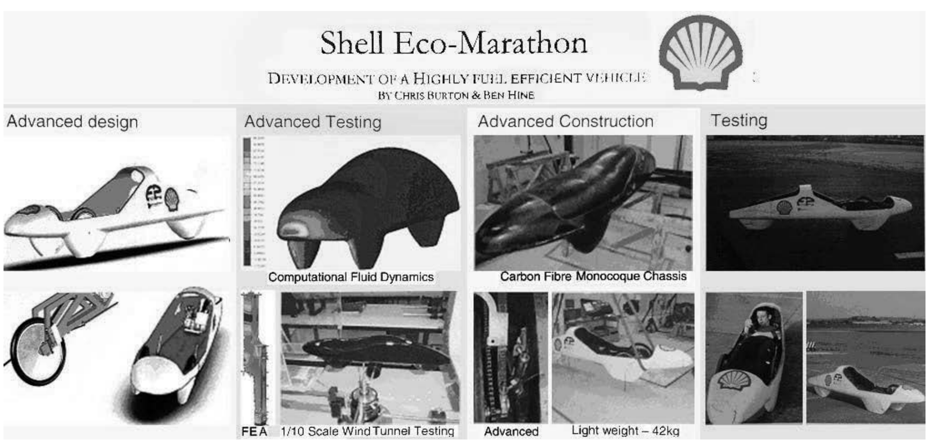


*Figure 3. Eco-Pro promo poster showing stages of design, construction and testing*

## 3 SHELL URBAN CONCEPT CAR

Vehicle two was designed in 2011 by a team of final year BSc Product and Automotive Design and BEng Mechanical Engineering students at establishment two and was powered by a hydrogen fuel cell. This car competed in the Shell Urban Concept category, offering a vision of a more sustainable city car. Students worked on a single aspect of the vehicle, gradually applying collaborative co-design techniques, reflecting and analysing, and developing into a cohesive team.


*Figure 4. Eco marathon sustainable city car with hydrogen fuel cell 2011*

In 2012, the project developed further with a team encouraged to utilise a learning approach based on the CDIO principles developed in 2000 by MIT (Figure 10) and saw the team develop a plywood chassis using cardboard composite and wood panels for a more sustainable structure. For continuity, a similar concept to the 2011 car was used for 2012. Instead of each student focus on separate individual projects, a cohesive project management approach was taken, encouraging team members to collaborate - sharing ideas and discussing problems amongst the group. This cohesive approach led to significant improvements in the design and materials used, with a more technically advanced flat-pack chassis which was commended by judges. Students' learning and comprehension was far greater using the shared and collaborative learning strategy, and the results were greatly improved - team went on to win the Shell Eco Design Award in Rotterdam 2012 [3].

*Figure 5. Shell Eco Marathon car 2012, and competition prize giving event*

Establishment 2 has since invested in a new, more advanced hydrogen fuel cell. The original fuel cell used in the 2011 car is used as a bench testing unit for educating students on this emerging and rapidly developing technology. This provides students with relevant practical knowledge, then challenges them to apply what they have learned to a real engineering problem using the latest technologies, with the later fuel cell showing great improvements in size, weight and efficiency.

*Figure 6. 1KW Original 2011 Ballard Nexa fuel cell set up for bench testing (left), smaller and more efficient 1KW Horizon fuel cell set up for the Shell car 2014 (right)*

The successful development of the Shell project has influenced the strategy for the design and engineering school's undergraduate CDIO program and also with the individual course strategies.

## 4 DEVELOPMENT OF LEARNING - CDIO

The teaching and learning principles developed across the two initial case studies have been applied to the undergraduate learning experience. A distinctive element of the previous Shell and Eco-Pro projects was the team composition, being made up of both engineering and design students. This has been introduced in a three month, first year undergraduate project. Mixed teams of BEng Mechanical Engineering and BSc Product and Automotive Design students work together to design and build components for Formula 24 electric cars. The design challenge has allows students some freedom whilst also providing a structure to ensure teams can cope with the challenge at this level. Students are introduced to practical skills of manufacturing and assembly with a standard front suspension design for each car. This facilitates students' understanding and interpretation of engineering drawings, which then they take into the machine shop and make, again and integrating connecting theory with practice to broaden and deepen their learning [4].

*Figure 7. Formula 24 First year CDIO design & make project, construction 2013*

This challenge gives students a standard rear subsection to ensure some consistency and to allow teams to concentrate on the design and manufacture of their own main chassis. CDIO encourages teams to develop their own solutions and either wood or steel were permitted chassis materials, all with specific cost constraints to bring a realistic parameter to the work. Teams were encouraged to experiment and take risks while considering the issues of weight, strength and sustainable design.

*Figure 8. Formula 24 First year project, final testing and timed race event 2014*

Teams tested the cars in the final week of the module and were awarded marks for cost, design, construction and assembly. Feedback from students showed excellent engagement in the project with students enjoying the combination of theory and applied practical experimentation. The skills developed through CDIO projects such as this will feed into the Shell project in their final year, allowing the students to build on previous knowledge while also challenging them further.

## 5 PEDAGOGY APPROACH – EXPERIENCING THE CDIO CYCLE

The CDIO initiative aims to provide students with an education that stresses engineering fundamentals set in the context of **C**onceiving - **D**esigning - **I**mplementing - **O**perating real world systems and products. CDIO has 12 published standards which prescribe improvements in 4 areas:

- Increase in active and hands-on learning (programme philosophy, standard 1)
- Emphasis on problem formulation (curriculum development, standards 2, 3 and 4)

- Emphasis on concept learning (design-build experiences and workspaces, standards 5 and 6, and new methods of teaching and learning, standards 7 and 8)
- Enhancement of learning feedback mechanisms (assessment & evaluation, standards 11 and 12) (the remaining standards 9 and 10 provide guidance on faculty development).

These standards therefore cover all 3 of the major processes in education – curriculum, pedagogy and assessment. By addressing these simultaneously, and aligning in support of each other, the CDIO concept promotes the notion that learning activities can be crafted to support explicit pre-professional behaviours [5]. By applying CDIO through eco-car, ie a motivational and aspiration activity which encompassing technical aspects, a successful learning vehicle has been established.

## 6 CONCLUSIONS AND FURTHER WORK

The Eco-Pro and Shell Eco Marathon cars show the potential for large, complex group based practical projects in a students' learning. They could be seen as collaborative major projects at a final year degree level, or as part of a compulsory postgraduate group module. Their complexity and level of sophistication is clearly demonstrated with the final vehicles, both being advanced and well developed prototype vehicles. On reflection, the project contained a number of features that made a huge impact on the teaching and learning from the students' and staff perspective:

a. The mixed teams of engineers and designers proved very favourable in a sharing of knowledge within the group and breaking down the boundaries between disciplines, a co-design approach.
b. The practical nature of the learning allowed a broadening and deepening understanding of theory, seen through the application of principles in an enjoyable and cooperative environment.
c. The projects themselves became effective learning vehicles to explain engineering and material principles, in particular sustainability, material selection, and technical issues such as fuel cells.
d. The Shell competition presents an opportunity for final year students to take part in a high profile realistic project, relevant to the many and various challenges they will face in industry.

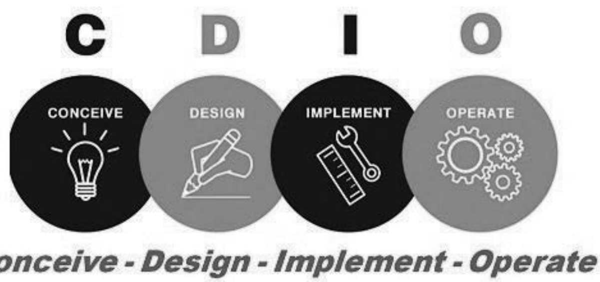


*Figure 9. The CDIO engineering education principle [6]*

The CDIO initiative was developed with input from academics, industry, engineers, and students. It is universally adaptable for engineering schools and is being adopted by a growing number of engineering educational institutions around the world. CDIO is currently in use in aerospace, applied physics, electrical engineering, and mechanical engineering departments, and a growing number of design courses. CDIO is based on a premise that engineering graduates should be able to: Conceive - Design - Implement - Operate complex value-added engineering systems in a team based engineering environment to create systems and products. The goals are to educate students to master a *deeper working knowledge* of the technical fundamentals; to educate engineers to lead in the *creation and operation* of new products and systems; and to educate future researchers to understand the importance and *strategic value* of their work; students report very positive results.

Project outcomes were disseminated through delivery of a first year module using the CDIO model. Feedback shows a positive experience for students with increased confidence about the manufacturing process, team working and the link between design process and final outcome. The planning and coordination of first year learning is critical for success - while final year students can at times be expected to be self sufficient, first year students need a much more structured learning journey. Detailed planning is required, with careful consideration of the learning aims and objectives to ensure the balance of challenge and achievable practice are met [7]. It is this alignment of curriculum, pedagogy and assessment that the CDIO programme appears to help.

The 2014 Shell Eco Marathon team were the first students to have completed a CDIO programme. While the current team are still working towards final competition, observation can be made when comparing the team to previous years. Initial observations at the time of writing show that:

1. Students show greater initative in tackling problems, and look for deeper understanding of technical issues such as fuel cell technologies, complex manufacturing and materials issues
2. Practical workshop abilities, materials handling and understanding have greatly improved, as have a desire to experience and resolve issues first hand, and in a cooperative, timely manner
3. Sketching, sketch modelling and informal impromptu design reviews and crits are used to communicate among the team much more than with previous cohorts or non CDIO groups
4. Problems and set backs are met with a positive desire to overcome and a ‘can do’ attitude.

The impact of the CDIO programme on student progression into the workplace is a key indicator of success, and a reason for implimentation into programmes [8]. Several students working on the current car have secured jobs in prestigious companies before graduation, such as Seimens and Dyson. Anecdotal evidence suggests that the CDIO programme was of great interest to the employers, indeed many now run practical assessment design and make type challenges, very like short open brief CDIO projects. All noted their contribution on the Shell team as a benefit in their job success, through a general increase in self confidence, efficacy, and sense of achievement.

By focusing on curriculum, pedagogy and assessment simulatenaously, and aligning these together by providing a stimulating learning opportunity, the CDIO approach has provided the students with improved compentency in professional skills such as problem solving, critical thinking and interpersonal communication skills. It has also promoted the emergence of a cooperative learning environment for the achievement of learning outcomes, which was certainly aided by the use of the eco-car model as an aspirational subject matter, a perfect learning vehicle.

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# TEACHING CROSS-DISCIPLINARY COLLABORATION IN DESIGN PROJECTS WITH ENGINEERING AND MEDICAL STUDENTS

**Stephan FOX[1], Vartan KURTKOUGLU[2] and Mirko MEBOLDT[1]**
[1]Product Development Group, ETH Zürich
[2]The Interface Group, University Zürich

**ABSTRACT**
In order to meet the med-tech community's high demand for innovation, the educational, cultural and communication gaps between medical doctors and design engineers need to be narrowed. Effective and efficient collaboration of members of the two disciplines is indispensable for successful exploitation of innovation in this area. While such cross-disciplinary collaboration is mostly learned on the job, students can already be made aware of the associated challenges in the academic environment. This requires teaching of cross-disciplinary communication, providing insight into the respective partner discipline and supporting the ability to work in culturally diverse project groups.
Here we present a case study of education in cross-disciplinary design based on a collaborative project between engineering and medical students. Several mixed teams are given a project assignment that is bound to produce cross-disciplinary communication challenges. The students are initially left to experience these to raise awareness of the negative effects on project performance if the challenges are not recognized and dealt with. Experienced medical doctors and engineers then coach the students in regular question and answer sessions, making them aware of the educational and cultural differences that produce the communication challenges in the first place.
We have seen high acceptance of this teaching approach among both student groups and have reached the main goal of raising awareness of the challenges associated with cross-disciplinary collaboration.

*Keywords: Teaching, Cross-Disciplinary, Project work, Engineering, Design, Medical*

## 1 INTRODUCTION

Cross-disciplinary and cross-cultural collaboration is ubiquitous in workplaces. Cross-disciplinary collaboration between engineers and medical doctors is indispensable for innovation in health care. The course outlined herein was developed to bring together engineering students and medical students to experience the rewards and challenges of such interdisciplinary work in a project based learning environment.

Future product developers must have the ability to work in interdisciplinary groups with a view to develop and validate innovative medical devices, as interdisciplinary collaboration allows for utilization of the most current knowledge and skills [1]. Motivated by real-life situations of miscommunications in interdisciplinary teams, this design course focusing on cross-disciplinary collaboration was created. Project based design courses are state of the art in education. Dym et.al [2] promotes project based learning (PBL) to enhance students' interest in engineering and to enhance their performance. Bell [3] describes PBL advantages as self-motivating, encouraging self-reflection and teaching to give constructive feedback. PBL is used for interdisciplinary teaching, e.g. to introduce mechanical engineers and product designers [4] as well as psychology students [5] to each other. The academic approach presented in this paper intends to go a step further and to acquaint engineers of different fields – mechanical, informatics or electrical engineering – with future medical doctors. In order to teach engineers- and physicians-to-be cross-disciplinary collaboration, the students need to develop a feeling for possible miscommunication and collaboration difficulties.

Therefore, one aspect of this educational approach is to create a perception for differences in mental models of different disciplines and to create an insight in misunderstandings that occur when mental models are compared between collaborators with the intention of sharing these models. Mental models

were introduced originally by psychologist Kenneth Craik [6] as instances of symbolization that are used to aid thinking, as a small-scale model of a person's external reality within its mind. Such a model includes the person's own possible actions and allows the person to try out various alternatives, decide for the best and react to future situations in advance. With utilization of past events, it allows dealing with the present and future. Mental models help to quickly understand new information and the sharing of mental models is an essential part of team communication [7]. This paper discusses the project work and the collaboration of the participants with a particular focus on the distribution of team roles and the sharing of mental models.
The goal of the cross-disciplinary design course is to educate students of different fields, cultures or communication patterns to work together in close connection. The intention is to teach them to be aware of the high possibility of creating misunderstandings and ways to avoid them with the concept of mental models. Furthermore, the students should be sensitized to situations that are created by preoccupation and prejudices, and introduced to possible ways to solve or simplify those.

## 2 COURSE DESCRIPTION

In this chapter, the setup of the course is described, the teaching goals are listed and the integration in the curriculum is shown. The students find requirements of the assessment and develop and build a prototype to complete their course.

### 2.1 Set-up

In order to teach cross-disciplinary cooperation, medical and engineering students are united in a supervised collaborative design project. After a general introduction to interdisciplinary communication and detailed background on the collaborative project, the engineering students receive tailored lectures on the anatomy and physiology of the relevant organ system. They then team up with medical students who have received a basic introduction to engineering methodology to collaborate on said project. In the process, they are coached both by engineering and medical faculty, receiving lectures customized to the project. The course ends with each team presenting their solution to a cross-disciplinary audience.
The main goal of this course is to demonstrate the differences in communication between the fields of medicine and engineering. Since such differences become the most evident during actual collaborative work, the course is based on a current project in physiology research that combines medicine and engineering. For the students, the specific aims of the course are to:

- Acquire a working understanding of the anatomy and physiology of the investigated system and knowledge of product development methods and project management
- Identify the engineering and medical challenges in the project and communicate them to the team members
- Develop and implement in mutual teamwork solution strategies for the identified challenges
- Present the found solutions to a cross-disciplinary audience

With 16 participants, four groups are created, equally divided between medical and engineering students. The course is intended for students from second year bachelor to first year master in medicine and from first year master on in engineering. Seven bachelor and one master student in medicine, as well as six master and two doctoral students in engineering were enrolled in the course that is rewarded with 4 ECTS points. The engineering students receive grades, while the doctoral students obtain attestations of course completion. The course comprises hours of lectures and two hours of tutor-supervised teamwork during 11 weeks. The students are graded on the final oral presentation (40%) in teams and on their individual performance during the semester (60%).

### 2.2 Course Assignment

A modified Krogh bicycle ergometer for measuring the power output of the quadriceps muscle group [8] (Figure 1) is used in current exercise physiology research at the collaborating institute of physiology. After they received tailored lectures about the other discipline, the students receive a brief introduction into their assignment and the purpose and use of the modified Krogh bicycle ergometer.
The subject sits on the pink wood plate wearing a customized boot connected to a flywheel, which is moved by motion of the lower leg of the subject.
The assignment of this course is to build an improved system to measure the power output of the quadriceps muscle group. Therefore in a first step, the participants need to find and describe the

requirements of this system, and define possibilities to enhance the system. The second step requires the students to develop different possible concepts for their device and to decide on one. In the following steps, the prototype is build and tested iteratively by the students to a final state where it will be presented.

*Figure 1. Modified Krogh bicycle ergometer to measure quadriceps power output*

## 2.3 Results

This chapter covers the results presented by the teams, starting with the defined needs and the different approaches resulting in the presented prototypes, while some special solutions and findings of the teams are reviewed.

### *2.3.1 Requirements*

The teams found certain requirements, which can be summarized as follows:

- More comfortable seat for the patient/subject, because experiments last up to 8h
- Adjustable seat
- Comfortable attachment of the foot
- Improved isolation of the quadriceps muscle group
- Possibility to change force on the muscle
- Possibility to analyze the force and frequency of the motion

### *2.3.2 Final Prototypes*

Team 1 designed a mechanical device (Figure 2a), with a wire rope hoist connected to a bucket filled with weights, allowing an increase of force on the fly by adding weights during the experiment. They used a bicycle computer to track the frequency of the leg extension.

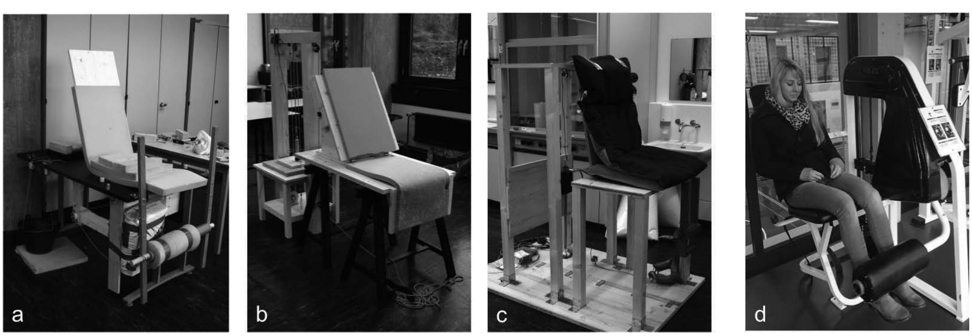


*Figure 2 a,b,c and d. Final prototypes of teams 1,2,3 and 4*

Team 2 designed a mechanical solution, too, but with a rack of weights, which are held down by a constant force spring (Figure 2b). The measurement is made with an infrared distance sensor and analyzed by computer. They also designed and built a seat adjustment feature and validated the isolated stress on the quadriceps with by EMG (electromyography).

Team 3 built a seat from an air mattress filled with Styrofoam to replicate a vacuum mattress (Figure 2c). Their force is generated by an electric linear motor and connected to the foot of the subject by a wire rope hoist and a lever. The programming and analysis is made by computer as well.
Team 4 bought a used leg-extension machine and planned to install a force sensor in the gear chain. (Fig. 2d) They initiated a detailed research on the requirements and found a machine with the needed requirements to be available to buy and went to test it. This finding was displayed in the final presentation.

## 3 KEY-FINDINGS

In this section, two significant findings are introduced. First, the evolution of team roles in cross-disciplinary teams is discussed with two examples, and secondly, a teaching approach in which a game called Pictionary is adjusted to be an educational exercise showing the students differences in the understanding of terms throughout different disciplines.

### 3.1 Distribution of Roles

A particular finding is the change in distribution of team roles as found out through observation and in the interviews afterwards. The idea of collaboration is unclear in the beginning, without experience in cross-disciplinary work, and can be developed on its own, or triggered by the educators. This is presented in two examples: In one group, the engineers had problems organizing a workshop for the assembly of their concept, due to language difficulties in communication with workshop personnel. The search took certain weeks for the group and raised frustration in the team, until one medical team member voiced his frustration about the situation to teaching staff. When asked if he tried to find a workshop himself, he realized that this did not occur to him in this project. Motivated by the educator, he adapted his role and organized a workshop for the assembly. This group delivered one of the most advanced prototypes in the final presentation.
Another participant reports in her interview that the medical students of her team doubted in the beginning whether they would be able to support the engineers in the development of the desired device. In the progress, the medical students supported the development with several ideas, most of the time very simple and a lot easier to realize compared to the engineers' ideas, and gained confidence as the project progressed. This shows that some participants come into this project with a preconception of roles and knowledge, but it is possible to help remove those in cross-disciplinary project work with steady support.

### 3.2 Pictionary

One specific teaching method produced extraordinary positive feedback. To demonstrate to the students the variety of mental models in different disciplines, the game Pictionary was adjusted and used in one of the lectures. There are two groups needed for the exercise. One person of the first team is given a term that has to be explained to the rest of the team by drawing and without talking. The teammates have to guess the word. The faster they guess it right, the better. In this specific case, teams were set up for each term in a specific manner as shown in Table 1.

*Table 1. Terms to be drawn, drawing and guessing teams*

| Term: | Drawing: | Guessing: |
|---|---|---|
| Pressure | Engineering | Medical |
| Cancer | Medical | Engineering |
| Stress | Engineering | Engineering |
| Infection | Medical | Medical |
| Filter | Engineering | Together |
| System | Medical | Together |

The groups with drawers and guessers of different disciplines are called cross-disciplinary and those with guessers and drawers of the same discipline interdisciplinary in this paper. This educational exercise shows that there are differences in mental models in different disciplines. As seen in the first example, pressure (Figure 1b) is drawn by an engineering student as a square with different force-arrows. The medical students had difficulties guessing the term. When asked to improve the drawing, a medical student drew the picture shown in Figure 1a, which represents a human with a blood

pressure meter. Interviews after the course show that the students kept this lesson in mind. They used this insight in their further communication. Team 4 noticed in discussions that the medical students of the team use different words for the same part of the device than the engineering students. This group therefore determined new words with agreed-on definitions,
It was not possible to show significant differences between the cross-disciplinary groups and the interdisciplinary groups because this would require the students to draw and guess the same term in different team-constellations. Nevertheless, the interviews show that the students saw the differences in mental models and adapted their communication as intended by the tutors.

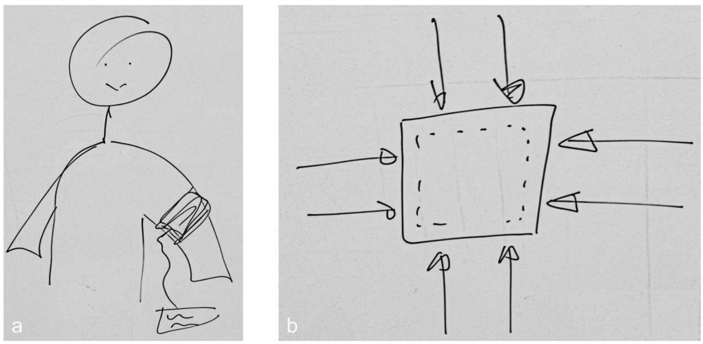


*Figure 3. Different visualizations of mental models of pressure by: (a) medical students and (b) engineering students*

## 4 CONCLUSION AND OUTLOOK

To teach future engineers and physicians to collaborate, communicational, cultural and educational differences need to be shown in order to raise awareness and teach how to avoid problems in a multidisciplinary design project.
The education project presented here received positive feedback from the students. The concept of teaching medical and engineering students together allows for a tight connection between the disciplines. The group composition of two medical students and two engineering students was well suited for the purpose of the course. One student left the course early due to a medical condition, leaving one group with only one medical student. This resulted in an unbalanced approach to the tasks.
The intense examination of the accomplished work in order to prepare the final oral presentation pushes certain reflection of collaboration and intensifies the cooperation. The students discussed the different aspects of their work, and were asked to present their experience of cross-disciplinary interaction during their project. The presentations show the different approaches and reflect the growing together as a group. This could be noticed by the use of technical terms of the ancillary discipline and the unified style of presentation. The audience consisted of members of different disciplines, from engineers without medical knowledge to doctors without technical knowledge.
The combination of lecture, project work and discussion meetings supported the teams with important knowledge in the beginning and encouraged collaboration with a mutual goal. The Question and Answer sessions with experienced experts of both disciplines allowed observation of differences in the teams. They also allow the tutor to recognize teams that are stuck on a problem which they cannot solve on their own and to get involved and sustain the team as early as possible.
In order to develop a sense for cross-disciplinary collaboration, one has to be aware of possible issues of communication. As explained in the section Pictionary, this exercise which requires only little time demonstrates impressively different mental models of identical terms. It can be easily adapted to other cross-disciplinary constellations, but the used terms need to be chosen with care, the ideal terms being abstract ones such as “system”.
Another important learning is the relevance of a real design problem and the possibility to build a system in reality. As seen in other design projects, the motivation is higher and the groups have the possibility to do their own need finding and to question the task by themselves. The possibility of building and validating their concepts in reality increases the risk of frustration, but boost the feeling

of accomplishment if the goal is achieved in the end. The design task has to be chosen very considerately. With the task described in this paper, the medical students are able to provide knowledge in the beginning, but as the needed development and construction is very labour-intensive and demands a fair amount of the engineering skills, some said they sometimes felt unneeded. Therefore, the task should be changed to a different technical system, which should be designed and built early and can be developed in several iterations giving the medical students the task and possibility to validate and evaluate the designed device and apply their knowledge. In summary, the presented educational approach can help students to connect and collaborate in a cross-disciplinary team and teach methods and awareness for their further education and future work life.

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# MEDIA AND REPRESENTATIONS IN PRODUCT DESIGN EDUCATION

**Maral BABAPOUR, Viktor HIORT AF ORNÄS, Oskar REXFELT and Ulrike RAHE**
Division Design & Human Factors, Department of Product and Production Development, Chalmers University of Technology

**ABSTRACT**
The creation of product form, involves embodying a potential function and intended use while defining geometrical, ordering features. This paper aims to elaborate roles of different media and representations in design activities intended to externalise form ideas (e.g. sketching, building physical models, digital modelling, etc). To understand and explain the role of media in design activities, design diaries were analysed. These were documented as part of a master course in Advanced Form Design in spring terms 2011-2013. For course completion, the students were expected to work in groups on a project seeking creative form ideas and solutions for a dinnerware product with a high level of novelty, aesthetic detail, and functionality. Design diaries were used as an educational method for initiating and documenting self-reflections on a weekly basis. The paper discusses how different media may support design, but in some cases also constrains creativity and ability to work with three-dimensional form. Understanding and explaining this may help students and practitioners engage with, reflect on, and value the roles of media for externalising ideas.

*Keywords: Externalisation activities, media and design representations, design process*

## 1 INTRODUCTION

The ability to make design representations is a central skill in design process. Designers engage in various activities, dealing with different media to externalise and represent their form ideas in e.g. sketches, physical and digital models. Design representations and the media used for creating them have different roles and support the designers' activities in various ways, e.g. sketching is considered the "heart" of the design process [1], "amplifying the mind's eye" [2], and supporting innovative design thinking [3]. Digital modelling, on the other hand, is regarded a threat in design, especially if the designers abandon their sketching practices [4], but has nonetheless become prevalent in product design education.

Design activities have a dialectic and reflective nature where designers respond to the changes they make in the environment [5]. This dialogue exists at different hierarchies: on the one hand, in the oscillation between the problem and solution space in the design process [see e.g. 6], on the other, between sketch moves. Schön and Wiggins [7] explain the conversational structure of sketching as a "seeing-moving-seeing" process that helps designers understand spatial relations. Goldschmidt [8] divides the sketching activity into moves and arguments relating to figural and conceptual properties of ideas (based on the inspection of sketches). According to Goldschmidt [9], creativity in the architectural design process is as a result of the interplay between these two types of reasoning. What these studies have in common is that sketching is seen as a preparation for further designing, built on and guided by prior moves. However, these studies focus on sketching activities, while research regarding the dialectic structure of other design activities (e.g. physical or digital modelling) is relatively sparse. In an earlier literature review [10], different ways in which sketching, physical and digital modelling facilitate design processes were identified. These involve physical (e.g. generation of alternatives), sensory (e.g. visual and tactile aid) and cognitive aspects (e.g. memory and retrieval aid).

The aim of this paper is to investigate how the identified roles from the literature review are manifested in empirical material, allowing for a comparison and further elaboration. Comparing and contrasting the roles that different activities fulfil, supports understanding of the dialectic nature of design and may highlight directions for product design education.

## 2 DIARY STUDY

To understand and explain the role of media in design activities, design diaries were used. These were documented as part of a course in Advanced Form Design (7,5 ECTS - master level) in spring terms 2011-2013 with a total of 38 participants. The students were to look for approaches that would lead to a creative and experimental yet structured generation of formal product solutions. Through an explorative process from abstract form generation to a concrete product design development, the students work in groups on a project seeking creative form ideas and solutions for a dinnerware product with a high level of novelty, aesthetic detail, and functionality.

### 2.1 data collection and analysis

Design diaries were used as an educational method for initiating and documenting self-reflections on a weekly basis [on educational benefits of using diaries see 11]. The students were to reflect on their process and the underlying motivations behind their activities using a structured template (see structured diary format see ibid.). Design diaries from the study year 2011-2012 (a total of 11 participants) were included in content analysis. A top-down analysis was carried out using concepts identified from the earlier literature review. According to Dey [13], ‘creating categories is both a conceptual and empirical challenge; categories must be grounded conceptually and empirically’. The collected diaries were printed and used for coding and memoing. This involved (i) identifying and grouping diary entries into sketching, physical and digital modelling activities, (ii) categorizing diary entries based on the literature review, (iii) identifying sub-categories to complement the literature review and (iv) tabulating the findings for comparison.

## 3 RESULTS AND DISCUSSIONS

Figure 1 presents an overview of the roles identified from the literature review and their manifestations in the design diaries. Important issues regarding the identified roles and their implications for design process are discussed here.

### 3.1 Conversations within and across media

The analysis of different activities in design diaries indicates a recursive relationship between materialising and inspecting ideas, where physical roles favour materialising ideas, and sensory roles favour inspection of ideas. The interplay between materialising and inspecting (or Schön’s seeing-moving loops in sketching) gives rise to cognitive roles (e.g. the emergence of new ideas), and thereby stimulates creativity. This applies not only for sketching, but also to physical and digital modelling. Furthermore, seeing-moving loops can be seen at higher conceptual level between different activities i.e. moves between sketching and physical modelling:

*[EM, W4, Sketching after a physical modelling session:] “Some of the workshop outcome was not very self-evident, but more a way of stimulating new ideas and thoughts, therefore it had to be interpreted right away.”*

Translating ideas from one type of representation to another was often reported in design diaries (e.g. sketching from mood-boards, collages, physical and digital models, see figure 2).

Reframing prior ideas using a new medium facilitates interpretation and leads to finding geometric relations that would otherwise be hidden in one representation. This is shown in studies regarding sketches, where restructuring and translating of visual components facilitated discovery of new information and patterns [see e.g. 14]. Moreover, materialising ideas in different forms facilitates discovery and correction of the poor assumptions that are not revealed in previous representations, and thereby, learning from previous mistakes. Designers learn from experimenting and communicating with models since they respond to physical behaviour [e.g. 15, 16]. This was especially clear when sketches and digital models were turned into physical models:

*[Av, w4:] “I found more inspiration and interesting shapes when working with the clay… [W5:] When studying our clay models and looking back on the board and analysis of our initial form category I realized that the transition lines between surfaces that are curved and multi force; curved in one direction and appears as twisted, are suitable for us… We found one particularly interesting form that triggered more new ideas, which we then decided to develop further.”*

*[AV, W7:] “We have built physical models in Styrofoam. Our measurements turned out to be slightly too big, why we decided to scale down the dinner set. It felt very valuable to make the physical models.”*

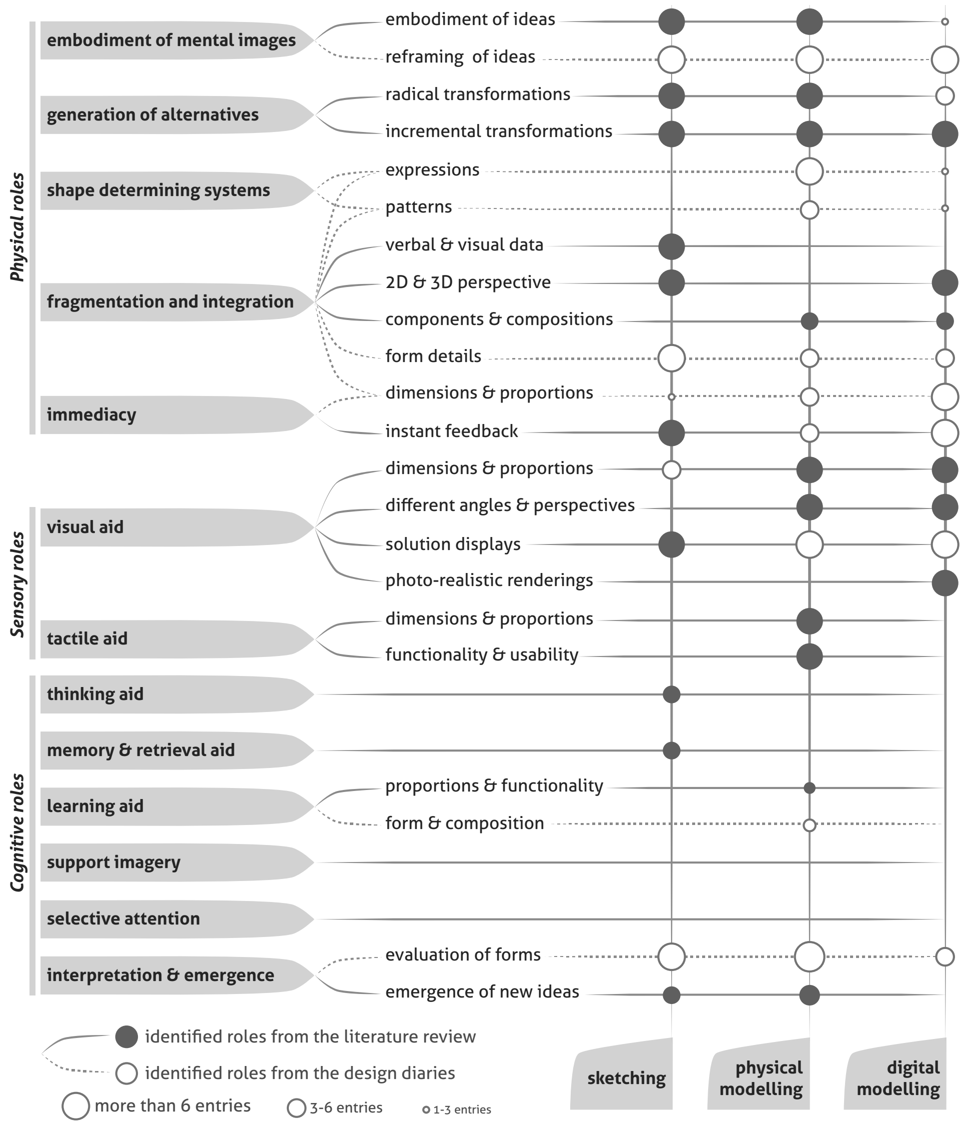


*Figure 1. Roles of externalisation activities in design diaries*

### 3.2 Immediacy and fluency

Diary entries regarding the activities that involve immediate feedback and are perceived suitable for 'fast form generation' included sketching, digital and physical models. Some researchers however have discussed that immediacy is exclusive to sketching which helps reducing complexity and relieving the memory load through appearance of an immediate trace of ideas provided that the designer has fluency in sketching [e.g. 17]. According to Robertson and Radcliffe [18], technical problems encountered in a CAD environment prevent the designers from instantly materialising their ideas, and thereby distracts them from creative problem solving. The remarks on immediacy of digital media in design diaries illustrate students' fluency and skill in manipulation of digital media facilitating idea generation without necessarily being bounded to and distracted by technical problems.

This may, moreover, lead to creating a large number of alternative solutions with little delay imagining ideas to materializing them and thereby stimulating creativity.
*[AV, W2:] "I found sketching to be a suitable first method of form development because that is what I found easiest and the fastest way to explore thoughts and try forms. To think with the pen."*
*[EK, W5, on clay modelling:] "We wanted to get a physical feeling of the shapes that we work with and also needed this to try some more complicated ideas in a fast way."*

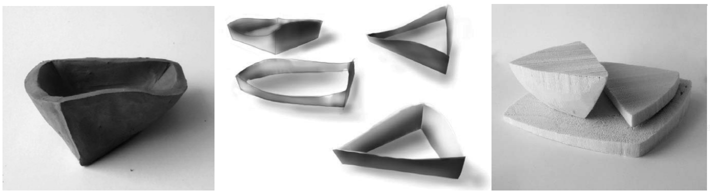

*Figure 2. Example of translation of solutions using different media*

### 3.3 Inspecting solutions

Inspecting and studying proportions and spatial relations was frequently mentioned in the design diaries, especially through using matrices and tables that were created as a structured display of prior ideas. One of the benefits of sketching, according to Goldschmidt [8] is the trace that is left which facilitates the designers' cognitive process. This also applies to digital and physical models, as the students made use of them parallel to their sketches in structured matrices (e.g. figure 3). Capturing and freezing traces of progress in physical models may however require additional effort.
*[AV, W2:] "We needed to organize and refine our selection of forms, so we cut out all the images and grouped them as we thought they belonged together."*

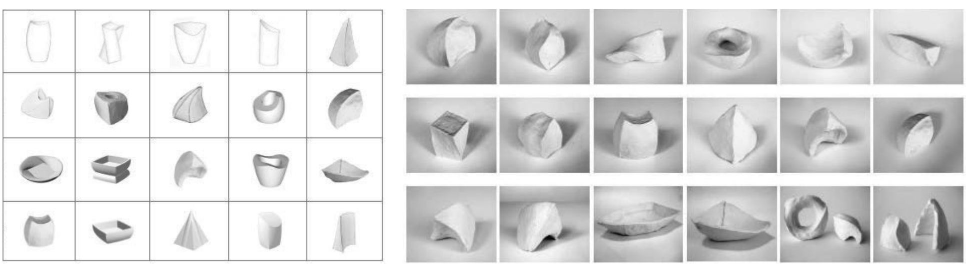

*Figure 3. Making solution displays for inspection of precedent ideas*

### 3.4 Media and representations as impediment to creative progress

#### *3.4.1 Fixedness*

In several cases, students seem to get caught up in a potential solution in an early phase of the process. Functional fixedness is "the tendency to be rigid in how one thinks about an objects' function" [19]. Jansson and Smith [20] found that the design fixation among engineering design students is due to the precedent solutions that designers look at, preventing them from finding innovative alternatives. Fixation on precedents can be seen in two ways: already existing products, and designers' own representations of potential solutions. The latter has been discussed by Robertson and Radcliffe [18], regarding CAD models causing resistance to major changes. In the present study, this was noted in physical modelling where a potential solution for one piece not only caused resistance against making major changes for that piece, but also governed the remaining parts of the design (e.g. figure 4):

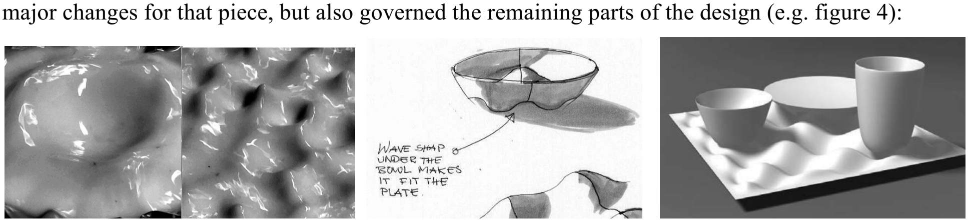


*Figure 4. Example of fixation from a modelling experiment with water, sound and vibration*

*"[JN, W2:] We decided to project light through a liquid that was under vibration by a sound source... [W6:] We wanted to imitate the shape that was generated from the experiments… We had a big difficulty on the pattern for the plate. We earlier decided to go for a linear pattern but we then realized that it is impossible to place the items on the plate. We spent a lot of time on this pattern without going anywhere… It was difficult to create the complicated and very organic shaped that we had in our mind and that was generated by our experiences by using CAD modelling."*

Designers' repertoires of potential solutions and form ideas may also play an important role in functional fixedness. Purcell and Gero [21] found that design fixations occur due to lack of domain specific knowledge and falling back on everyday experiences. A limited repertoire may also contribute to premature fixations, where the designer conforms to the solutions that are easily achievable different media.

#### 3.4.2 Shape determining systems

Different activities give rise to and encourage certain form solutions, which can be seen both as contributing to a larger pool of choices, and more creative freedom but also as constraining what one can do if one only relies on a specific medium. Pye [22] discusses that drawing gives shape to and determines forms that are made up geometrically, since it is easier to make them using drawing instruments and communicate them with others in terms of basic elements. Robertson and Radcliffe [18] also point out a problem with CAD systems where the designers' ideas stay limited to not only what is possible by the medium but to what is easiest and most available.

This was noticeable for all of the activities in design diaries. For example, the difficulty to use patterns while sketching discouraged the students from experimenting with patterns in their form solutions. Smooth and curved forms were encouraged, while creating solutions with thin walls were discouraged when making clay models. Making sharp transitions, working with concave and convex surfaces in oval shapes were found to be easier in the CAD systems used by the students. Making organic and complex shapes was on the other hand found difficult according to the diary entries.

By making a form easier or more difficult to achieve, media have a role in determining and governing designers' solutions. This can lead to premature fixedness and resistance to major changes, especially if designers have limited form repertoire and lack of experience with the specific product type.

#### 3.4.3 Mental gaps

One of the main problems mentioned in the diaries, is an incongruence of students' mental images and their design representations, e.g. how a physical model looked different from the sketched ideas, how the digital model is incongruent with its prior representations, or how sketching lacks three dimensional feeling. While these may be shortcomings of the medium, they can also be due to ones' limited spatial thinking abilities or skills in manipulating the media. Research regarding designers' spatial thinking ability is however limited.

### 3.5 Reflections on the use of diaries

Investigating the interplay between different design activities requires longitudinal studies that span over a whole design process. Using diaries as a data collection method allow for recording these activities along with designers' self-reflections. Diary methods, however, involve a delay between the occurrence of the event and data collection, it does not capture the on-going cognitive aspects of design activities (e.g. supporting imagery and selective attention were not exhibited in design diaries, see figure 1). To capture the cognitive roles that different activities may involve, concurrent data collection methods e.g. think a loud may be more appropriate.

## 4 CONCLUSION

The roles identified for different externalization activities may in design education serve as a platform for mediating discussions, and reflections on the use of media and representations. However, they concern students' activities when designing dinnerware objects. Further studies especially with other products types may complement the findings.

Design progress can be seen, as interplay of moving-seeing not only within one way of externalising, but also across different media. In the design diaries the students engaged in a dialectic process when translating their ideas from one medium to another. This requires conversing both with precedents and the evolving translations, providing opportunities for reinterpretation of ideas. Moreover, learning may happen when translating ideas from one medium to another. Creating educational situations to encourage the students iterate more often using different media, may result in reaching more well-reasoned solutions.

The extent to which students can learn from this process depends on their skill in manipulating media. The results from diary analysis show that eloquence in using digital media leads to perceived immediacy, creation of more alternatives, and overcoming limitations of shape-determining systems. This accentuates a need to help design students become more skilled in using different media, thereby enabling a fluent exploration of novel solutions.

## ACKNOWLEDGEMENTS

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# THE RESEARCH PAPER AS AN OBJECT OF COMMUNICATION IN INDUSTRIAL DESIGN EDUCATIONS

**Bente Dahl THOMSEN[1] and Lars BOTIN[2]**
[1]Department of Architecture, Design and Media Technology, Aalborg University
[2]Department of Development and Planning, Aalborg University

**ABSTRACT**
The writing of research papers gives students at industrial design education's the opportunity to gain experience with design research and papers as an object of communication. Design research is an interdisciplinary field that is both relatively new and also has a fuzzy borderline to the professional disciplines which designers usually work with or compete with. Design research is in nature quite an abstract field of science, which is a big problem for students who for first time are going to design a scientific approach for their study's field. It is an interesting problem because it reflects a symptom of design research in general. In order to exemplify and provide an overview of useful approaches, this study develops archetypal design research approaches where the abstraction level is adjusted so that they represent a real support for new researchers.

*Keywords: Design research approach, science studies, object of communication*

## 1 INTRODUCTION

Scientific research and industrial design is a fairly new combination at university programs, and to a large extent they represent the classical dualism between theory and practice. 'The research paper as an object of communication' is an attempt to bridge this dualism and create a meaningful space for reflection on action. In 2005, the Danish Ministry for Research, Innovation and Education decided that all engineering educations should have compulsory courses in philosophy of science, because a need for scientific competences in methodology and reflection had been detected in the educational system. The courses that we are going to deal with in this paper are one such attempt to infuse methodological credibility and validity into the programs, and at the same time to teach the students to communicate in a proper language and style. This does not mean that we are trying to establish a closed and specific scientific lingo on industrial design, on the contrary, we are trying to open up for variety and hybridity in creating this 'object of communication', because it is precisely meant for communication in contextualized, cross-disciplinary and engaged environments.

There are several challenges to confront when research papers are produced and discussed. It is how we meet these challenges that are at the core of this paper. The main challenges are: definition of the scientific foundation of the enquiry, lack of identification on how phenomena are to be read and understood, lack of structure in dealing with the topic/problem of the paper. There seems to be very little documented experience (at least in a Danish context) on how to frame industrial design in a scientific and theoretical perspective, which is probably the reason why students are finding it difficult to produce research papers of scientific and methodological quality in the spirit of 'mode 3' knowledge-production [1]. The two contending 'modes' are also a 'problem' in this case, because they use models and theories that both rival and complement contextualization, engagement and cross-disciplinarity. Furthermore, the core of industrial design in this perspective is not a fixed, frozen or clearly defined entity. On the contrary, it is in a process of constant becoming and as such impossible to classify and standardize. This dynamic and emergent situation of uncertainty is of course difficult for the engineering students to handle, because in general they are used to clear and certain answers delivered by mathematics and physics.

In order to give some sort of understanding of the processes in knowledge-production, which is not based on certainty and truth, we have tried to introduce the 'scientific logic of discovery' as visualized by Imre Lakatos. Lakatos' model shows how there are a core of claims and reasons, and how this core is immersed in an environment of heuristics. Knowledge-production in this perspective is to work with negative and positive heuristics where we (critically) question the reasons and claims of the core. This means, in our reading, that the core is constantly under critical pressure and that claims and reasons change as evaluation processes are developed and take form as 'objects of communication', e.g. research papers and articles.

Heuristics in a scientific perspective has to do with discovery, and how to act in order to be able to make discoveries that expands and enhances our knowledge of the world and reality. The ways of heuristics are not defined as such, but depends on, or are interdependent with, the context. This means that the scientific work, the research paper, is entangled and intertwined with the context, and that the importance of the context should manifest itself when it comes to clarifying values and interests present in the context. And this is at the foundation of all scientific discoveries. When structuring and designing the research paper in an industrial design context, it is obvious that we cannot exclusively depend on the extreme heuristics of random (negative heuristics), but should complement with positive heuristics where clearly identified 'tools' and theories are at hand. In this way, we pose critical questions where we challenge the claims and reasons of the core. This means that Lakatos' protective belt needs a redefinition, because it is uncritical in its protection, hence pointing towards Karl R. Popper's emphasis on critique in relation to logical deductive thinking.

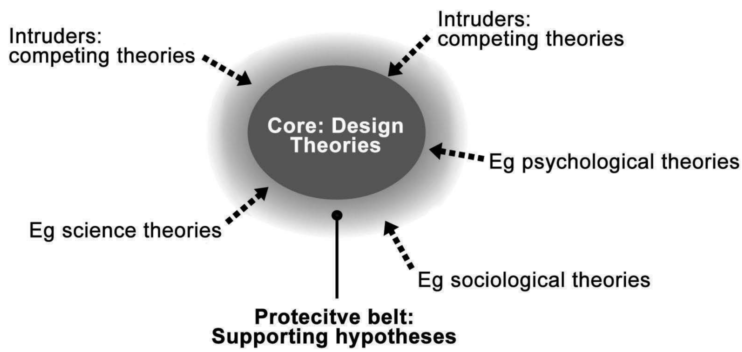


*Figure 1. The hard core of theories[1] by Imre Lakatos [2]*

Chucholowski et al. [3] have recently made an attempt to systemize and categorize the relationship between activities (practices) and research (theories) in design processes, where they establish a taxometry based on the intertwinement of activity and research. Their model addresses a branch of design which focuses on the technical, functional and practical elements in the process. In comparison to the approaches (13) that are present in this specific paper writing course, the taxometric model could be classified as one approach out of several, because we find that there is a lack of context in the taxometric model. There is a lack of cultural and social practice and reflection, dealing with the importance of the user as a social entity, the importance of aesthetics as a clearly defined parameter in the design process, the importance of history, e.g. the genealogy of process and design, and the importance of philosophical reflection on technology. The 13 approaches that constitute the methodological framework of the course mirror this integrated and holistic understanding of research in design, where science and engineering, social studies and humanities meet in the 'critical belt' engaging with dynamic and transformative core design theories.

Emergent studies and programs like industrial design should be framed in dynamic and transformative ways, because the core is not defined and probably never will be. How do we handle this situation of uncertainty and heuristics in an educational setting, which to a high degree is layered within the framework of empirical-analytical science? How do we create the scientific and research framework that promotes critical and reflective thinking in the research paper as an object of communication? And finally how do we make way for practice to be part of such reflective thinking?

[1] The figure is inspired by a figure of Martina Maria Keitsch

## 2 THE STUDY - PREMISES

Presentation of the frame for the "archetypal design research approach" is assumed to be necessary to give useful understanding of the study's result. The frame consists of two courses with contents of philosophy of science in industrial design education and the tools of production of research papers as well as The Pentagon of Scientific Enquiry [4]. The last-mentioned model is an actual tool, but the model plays a leading role given that it helps gather and organize the results of other tools. Pentagon also constitutes the taxonomic backbone for building the design research approach.

### 2.1 Philosophy of Science in Industrial Design Education

Industrial design is characterized by multi- and interdisciplinarity, which creates a number of problems when it comes to designing the curricula on philosophy of science for the course. On an ideal level the study aims at interdisciplinary processes and solutions, but in reality these are multi-disciplinary, which means that the various disciplines involved in the process are not connected and even less intertwined. This means that ontology, epistemology and methodology often are contending the field which leads to confusion and frustration among the students.

The curricula of the courses are focused on the concept of the matrix of paradigm. This means that we search for theories and methods that will enable some sort of core construction of the discipline. We do that by introducing to Thomas S. Kuhn's definition of the paradigm [5], which we supplement with the ideas of Karl R. Popper on the 'logics of scientific discovery' [6]. It is especially Popper's creed in abduction as reasoning that we find relevant for a program that is both revolved around science and artistic creativity. Furthermore, we introduce the students to circular reasoning and fusion of horizons in the perspective of Hans-Georg Gadamer [7], where the eminent qualities of the hermeneutic circle are discussed. Besides that we also discuss the potentials of empirical experience through our senses based on the ideas and models by Ernst March and Hal. R. Varians [8]. This ontological, epistemological and methodological patchwork is necessary in order to embrace all the practices and knowledge types of industrial design, and certainly it makes the students understand that this discipline is multifaceted and trans-disciplinary. The weakness of the construction of the patchwork is that the different positions have very loose, if any, connections, they also have different rationales, different terminology, and different criterions for validity, credibility and truth and different aims for what concerns the actual knowledge-production. This means that there are constant clashes and contentions, which are hard for the students to handle.

We think that the curriculum is in need of a refurbishing where we emphasize the hybridity of the education, and make it clear that the program is 'in between' disciplines. We think that there is a need to pinpoint the multiplicity of competences that constitutes the role and identity of industrial design, where we point at the capacity to construct models and design based on mathematical and physical principles, the capacity to understand societal and cultural consequences of technology, the capacity to understand use/user of technology. This requires 'a hybrid imagination' [1] where things are intertwined and we enable and support connections and translations in between disciplines and competences, which in this case is layered within the education itself. In the following, we shall look into the actual practices in the course, and we will discuss the tools that we use in the production of research papers.

### 2.2 The Tools of Production of Research Papers

Students in bachelor programs, that for the first time have to prepare a paper about a professional design subject, have, in addition to the theoretical knowledge about design research, a need for tools which supports the paper creating process. The tools which were included in the paper creation are presented here briefly, because they provide a central part of the framework, to which "the heuristic design research approach" belongs. The tools are presented in next to the activity they contribute to and in the order they are brought into the process:

- Topic selection ⇒ thematic structured catalogue which exemplify and inspire to selection of a topic within three themes: Form & Aesthetics, Method & Process and Technology & Production.
- Selection of keyword ⇒ mind map, where the chosen topic constitute the core. All the students help each other by working on each other's mind maps.
- Knowledge about the genre and experience with scientific review ⇒ presentation and review of a published E & PDE paper in two-man teams to the rest of the students [9].
- Literature search ⇒ online searching by Primo was introduced and started up with supervision.

- Relevance checks ⇒ a verification of the professional relevance of chosen topic on the basis of a working title, research question or problem that will be analysed, and a brief description of the different needs of knowledge the topic offers.
- Progress in the creating process ⇒ an introduction to writing clusters in association with synopsis[2] feedback and rewriting of paper drafts [10].
- Practice-based research ⇒ is exemplified during an excursion to companies such as Møller-Jensen Innovation & Design Aps, Kontrapunkt A/S, Damvig Develop A/S and to institutions such as MindLab, Danish Technological Institute and Danish Patent and Trademark Office.

The students have also been presented to a number of examples of the content, overall structure and requirements for quality of good research papers [11].

### 2.3 The Pentagon of Scientific Enquiry

Pentagon is used at many Nordic universities as a tool to ensure the scientific foundation of the student's research [4]. This study's students were also presented for this tool. The Pentagon corners focuses on: 1. *Research question* ⇒ what do you ask about? 2. *The research's academic purposes* (potential use) ⇒ why do you ask? 3. *The research's empirical* ⇒ which substance, data, phenomena, etc. do you ask for? 4. *The research tools* ⇒ which theories, concepts and professional methods, do you ask with? 5. *The research's approach* ⇒ how do you ask? The design professional topics the students preferably choose to treat are either based in the reality they live in or have grown out of something that has not functioned optimally during the study. As mentioned above, the Pentagon of Scientific Enquiry gives a general template for each research, but it is also a challenge given that the tool's activities must be specified relative to the topic's professional field. Despite the fact that subject-specific context is given and the issue is selected in relation to a theme, the interdisciplinary field makes it difficult to select an approach for the research. When the synopsis has been based on review of relevant literature, feedback on each synopsis from the writing cluster has been good support. The course introduces many theories to give as many students as possible a good starting point for their investigation and for contributing actively in discussions. It has also been emphasised how important the "design research approach collection" can be as notes for remembering. Preliminary studies suggest that the notes are especially helpful when recalling the assumptions, approaches and presumptions about the character of returns.

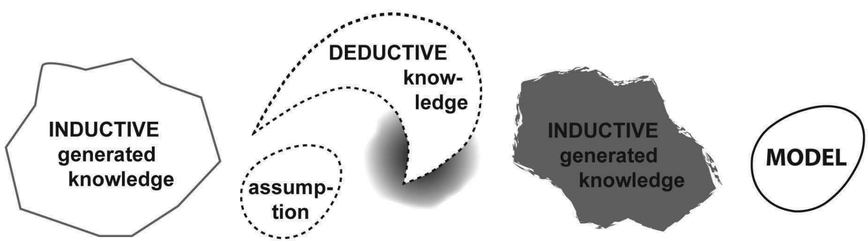


*Figure 2. The double-focused approach*

A special need arises in situations where the selected topic is new or in the absence of scientific treatment in relation to the design profession. It happens when only sporadic knowledge is available in practice or when the problem is addressed only in a science field that is not directly related to the design profession. For that reason, the first approach was to give input to these topics without design professional literature, but with an incipient interest in practice. This approach is based on the double-focused approach [12], which is based on an inductive approach, where one without preconceived opinions gather knowledge through field studies, investigation of the documentary sort and what else the situation might offer. The understanding of this collected material forms the basis for the deductive approach of the next phase. The first idea of a possible answer to the research question or a solution to the problem is only rarely complete; but enough to define a previously uncovered area which a new

[2] The synopsis should include: Title of the paper, the state-of-the-art, problem / research question, the approach to the study of the problem, the theoretical background of this matter / method of analysis / hypothesis, if possible ideas for solving the problem and a proposal for paper's outline and references.

study with an inductive approach may shed some light on or result in a delimitation of the use of a theory. See Figure 2. Such an exchange interaction between the inductive approach and the deductive approach can be used to cultivate new fields where the approach can either lead to an answer, outline a model or a method of investigation.

## 3 THE STUDY - PROCEDURES

The papers that are the subject of this study are the results of the two courses Philosophy of Science 2007-2010 and Theory, History and Analysis 2011-2013, which both were of an extent corresponding to 5 ECTS and offered to students in the third year of the bachelor's program. The number of students participating in the Philosophy of Science course, which was offered to architecture students as well as to design students, grew from 100 to 150 over time. The other course, which was offered only to industrial design students, had 26-32 participants. It may be a surprise that this study is based on the papers and not on the courses' theoretical and methodological basis, but both courses have suffered from the fact that the scientific level of abstraction did not match the students' initial proficiency. The aim of the curriculum was high, since the purpose of paper production was "*to convey the student's independent research of an important theory position or method in industrial design professionalism."*
In the light of these experiences attained in the courses, the study's purpose with the design research approaches was first and foremost to support practically oriented students and students, who have not evolved from "solving tasks" to define, delineate and answer research questions yet. The papers from the two above-mentioned courses were scrutinized for fragments of known and unknown scientific approaches, with the aim of identifying the approaches and isolating missing link between the fragments.
Subsequently, the preliminary design research approaches based on this scrutinising were corrected so that they represented a pattern of scientific approaches. Experimental investigation has been difficult for students to fit into the short course, therefore it has been necessary to supplement the collected design research approaches with elements that can inspire the students to make such investigations. Finally, some testing on this collection of "archetypal design research approaches" was necessary in order to get an answer to the study's research question: do such a "heuristic design research approach" really support the students' design of approach to the research. The first criterion of success is the clarity of procedures, and the second is the emergence of new approaches possibly developed by combining "archetypal design research approaches".

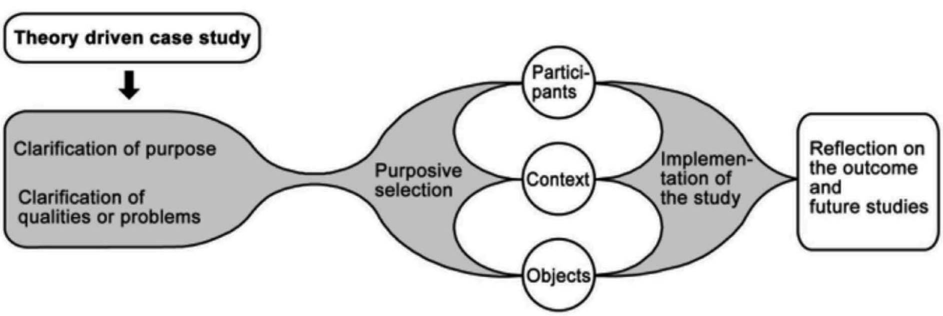


*Figure 3. Design research approach to a case study.*

### 3.1 Exemplification of Design Research Approach

Roughly a quarter of the students saw the preparation of their papers as a chance to challenge the theories they had more or less good experience. Typically, the motivation is in the dissemination of a theory field of application to industrial design or in the developing of theories to improve the match between theory and practice (the students' own project practice). One example of a title of a design research approach is: Case study of theory testing. One thing that characterizes the approach to such a theory-driven study is that it is purposive. The theory-driven studies completed by our students aim to provide an abundance of information, therefore they are qualitative studies. The purpose of the student papers is mainly to provide guidelines for design of something or recommendations to the design process. Rarely, there is time to complete more than one case study, however the visits to various companies during the excursions often present several cases for study, however the reflection on each case is not made until after all visits are completed, therefore we are not talking of serial case studies per se. The model for approaching this type of case study can be seen in Figure 3. The approach is idealized based on the description in the booklet: "Selection of cases" [13]. Where the concept "object" is used in the model, it is used as "object of communication".

## 4 RESEARCH FINDINGS AND IMPLICATIONS

Our study showed that the collection of "archetypal design research approaches" both contributes to increased quality of student surveys and to the communication of their researches, given that the collection has inspired the students to describe, to a greater extent than earlier, their approach in the synopses. The collection of approaches is still rather limited, which means that the possibility for creating hybrids for investigation and understanding is restricted. This is for now a weakness in the set-up. In the future we will stress the importance of heuristic hybridity in experimental investigation. Archetypal approach for case studies and experimental investigations has increased the incidence of case studies and given the students the courage to throw themselves into experimental investigations. The study also revealed that the archetypal approach does not sufficiently exemplify how the parameters, which are subjects of the research, can be described as recognizable phenomena or graduated measurable qualities. Unfortunately, we found that instructed literature searches were not sufficient to get a clarification of all the state-of-the-art. Approximately one third of the papers were based solely on searches completed in Google Scholar. This is a dilemma between a desire for a small manageable collection of "archetypal design research approaches" that all students can use as inspiration for choosing both topic and approach and a desire for detailed description of approaches that also exemplifies the construction of parameters. In order to solve this dilemma, we suggest that the collection of approaches is combined with a design research taxonomy model like the one mentioned above. Such a model will accommodate literature, where the students can find examples of parameter construction.


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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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# ROADMAP AND TOOLBOX FOR THE IDEATION STAGE OF THE DEVELOPMENT PROCESS OF PRODUCT SERVICE SYSTEMS

**Ivo DEWIT, Dries DE ROECK and Chris BAELUS**
Product Development, Faculty of Design Sciences, University of Antwerp, Antwerp, Belgium

**ABSTRACT**
Product service systems (PSS) provide an opportunity to create innovative interactions between consumers, the products and services they use and the providers offering these products. In contrast to traditional services related to products, the service component of a PSS significantly adds value to the experience of the consumer. Within the context of this paper, we add 'smart' to the PSS, because advances in information and communication technology have made it possible to combine products and services in innovative ways. Although PSS introduces new elements to a design process that require a thorough rethinking of how designers should relate to this specific kind of products, the main challenge is to manage the variety of underlying design processes. Especially in relation to the front end of innovation, there is a need for new and adapted tools in order to explore emerging PSS opportunities. In this paper, we report on a ten weeklong project. This project was targeted at first master students in product development, as a case to explore how existing service design tools - modified with a specific PSS focus - can be introduced in the early stages of PSS concept creation and definition. We use the creativity support index (CSI) as a metric to evaluate the tools used. The paper brings forward several lessons learned related to the implementation of the adjusted tools for a PSS design project.

*Keywords: Integrated product development, connected products, product service systems, ideation*

## 1 INTRODUCTION

'Smart' product service systems (PSS) [9], based on electronics, advanced information and communication technology are introducing several elements to a design process that require a thorough rethinking of how designers should relate to this specific kind of product category. The main challenge is to manage the variety of underlying design processes at play during the design of connected 'smart' PSS: electronics design, software design, service design and product design. By merging these disciplines, the design opportunity is that the user experience and interaction can be placed as a central element instead of placing technological possibilities as a central element. Often an 'intangible' service component is included as part of an ecosystem or product service system (PSS), and therefore requires a different design approach that copes with an increased complexity. Especially in relation to the front end of innovation, there is a need for a set of new and better-adapted tools, based on service design, usability and user experience design in order to explore the opportunities provided by emerging PSS concepts.

## 2 METHODOLOGICAL APPROACH

### 2.1 The PSS project in design educational setting

Within the 'integrated product design' (IPD) project, an interdisciplinary approach was used as a case to explore how existing tools can be introduced during the conceptualization of PSS. It represents a workload of 14 ECTS (European credits) and is compulsory for first year master students. The project focuses on the development of competences in product service system design. The focus is both on concept generation, definition and integration. During this ten-week project, fifty-two design students participated. They were evenly divided in seventeen groups of three students each. Each group was challenged to define innovative concepts to enrich the interaction during the important moments of life, such as childbirth, first job, retirement, buying a house, etc. These were defined based on the concept of a ‘lifeline’, which is a technique used in psychological analysis [7]. The exploration of these (predefined) ‘nodes of life’ started from defining the context, the interaction, the experience and the functional and emotional aspects related to actors and activities present within each ‘node’. Based on this exploration, new opportunities for PSS were to be defined. During this design assignment, an interdisciplinary team of five people guided the students. The team consisted of two assistant teachers in product development that provided educational guidance and design input. Two doctoral researchers introduced and weekly supported in the design of PSS, one with a focus on interaction design and prototyping of complex systems [2], the other on the design of PSS with a focus on the user experience [4]. In addition, one professional member from a service design agency was included to introduce and monitor service design principles and tools during the process. The follow up of the teams was based on a weekly presentation using the templates provided by the PSS toolbox, thus showing a standardized visualization of the projects and allowing a comparison between the different projects and their progress.

### 2.2 Product-service design, a nexus between academics and industry

In order to start from a given set of tools, collaboration was set up with a design agency which is specialized in user centred and service design. Together with Design Flanders, the service design agency updated their existing *service design toolkit* in the context of the ‘spider project’ [10], which supports public service innovation using design in European regions. The toolkit [3] contains a set of ten service design tools and related templates, which - together with the design agency - were modified with a specific PSS focus. The goal of this toolbox was to support the exploratory research and interdisciplinary analysis, resulting in user insights, design requirements and innovative PSS concepts. A toolbox of student activities was set up and every week a set of design tools was introduced, each tool having a specific goal.

### 2.3 The PSS toolbox overview

The toolbox followed the distinctive path of the front-end of innovation, its characteristics and principles according to current research on PSS [4,5]. The tools in the toolbox were provided as printed templates and canvasses, which aimed to provide students with a structure during the early phases of their design process to explore, ideate, define and finally design innovative PSS concepts (Figure 1).

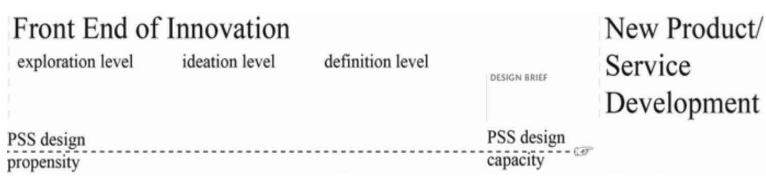



*Figure 1. FEI - process*

Chronologically, the introduced tools were:

*i. Stakeholders experience journey*

This first tool supports the analysis of the experience of the user with respect to the specific ‘node of life’ and enables to choose a user/provider combination of the product-service. It aims to identify key stakeholders; experiencing the node, relatives and people involved in e.g. care or support. The tool allows a mapping of key moments for each stakeholder. These key moments provide insight into what the stakeholder is doing whether s/he feels positive or negative about that activity.

*ii. Context and objectives mapping*

It is important to come to a better understanding of the user / provider interaction(s). The context and objective mapping tool is a first step towards the product-service promise and thereby creates an understanding of the providers’ goal, the main needs and motivations of the user, who the users are and different thresholds, trends, limitations and conditions of the product-service. The tool also helps the team to prepare the field research (interviews) and what you want to examine exactly.

*iii. Research questions*

This tool builds further on the second tool (context and objectives mapping) by preparing the interview. It makes the team think about the type of user they want to query, the event stage (pre-event period, event period and post-event period) regarding the context of the experience, other stakeholders and the activities that took place. Additional questions are considered up-front that the design team can ask when discussing their envisioned PSS experience with the user.

*iv. Stakeholder interview*

The research questions tool is used as guidance to interview the stakeholder. User, event stage and context are defined through the interview and serves to test previous assumptions. Doing so, new insights are identified related to the target audience. In the discussion related to the most positive and negative experiences, the additional questions helped discovering underlying reasons.

*v. Persona dimensions*

The persona dimensions tool allows design students to create personas through capturing the users' needs, identifying user attributes that affect your PSS. After identifying several attributes relevant to key stakeholders within the PSS, several combinations of these attributes are made. Selecting the opposite user attributes that affect the perception of the product-service combination, enables to determine realistic combinations of dimensions that can form a fictitious person.

*vi. Persona template*

Together with the persona dimensions tool, this template helps the design team to define the target audience and create different user perspectives, the goals and most important needs of the future product service system in later stage design.

*vii. Actors map*

It is important to get a clear picture of everyone involved and the role they play in the system. The actors map enables the designer to create a detailed mapping of the activities and actors that play in different event stages in the system. It allows them to identify the value exchange that takes place, which is crucial to combine relevant actions and actors into promising PSS combinations.

*viii. Design challenge*

This template helps to set more focus and determine what you want to design during the next phase, it is a rephrasing of the initial product-service promise into a design challenge. The design team can characterize their PSS with certain key values and decide on the boundaries of the project. A designer's approach using a diversity of visualization methods is then used to create a general identity of the envisioned product-service.

*ix. Design requirements*

The group determines the opportunities for innovation from the design challenge and translates them in requirements concerning context of use, interaction, rational and emotional objectives, services and product components. Afterwards the eight most important requirements are selected from this list.

*x. Lotus blossom*

The aim is to retrieve important characteristics through inspiring examples in different contexts and combine them with the eight most important requirements from the design requirements tool. The characteristics of the examples provide as input for a further product-service system definition.

## 3 CREATIVITY SUPPORT

### 3.1 Background

With a wide range of definitions and theories, there is no single agreed-upon methodology for recognizing and evaluating creativity. Thus making it particularly difficult to evaluate how well a tool that supports a designer during a creative process is actually helping a design team. Since the goal of our research was to understand which part(s) of the provided service design toolbox worked better than others, we chose to use the Creativity Support Index as a metric. The Creativity Support Index (CSI) [1] is a psychometric survey designed to assess the ability of a creativity support tool to support the creative process of its users. Its theoretical foundation is based on concepts from creativity and cognition support tools, which includes Schneiderman's design principles for creativity support tools (CST) [8]. The CST we refer to in this paper is the previously discussed PSS toolbox, i.e. the service design toolkit adapted with a specific PSS focus. The CSI consists of a standardized survey, which helps researchers and designers to evaluate the level of perceived creativity support, provided by a certain tool or method. The CSI survey is typically filled out after a participant has finished using a specific tool. The CSI consists of two parts: a rating scale section and a paired comparison section. The rating scale section, for which each agreement statement (Fig.) is answered by the participants on a scale of "highly disagree" (1) to "highly agree" (10), assesses 6 different factors; *Collaboration,* *Enjoyment, Exploration, Expressiveness, Immersion, and Results_Worth_Effort*. The participants complete this section twice, using different statements for the same factors and without seeing factor names or knowing they are grouped. The higher factor score indicates that the tools better supports that factor, with a maximum number of 20. Afterwards, the participants also complete a paired-factor comparison section (Table 1), where each factor is paired against every other factor for a total of 15 comparisons. In these comparisons, the participant is asked which factor in a pair was the most important to them, for the activity that they just completed. This allows us to look at the reliability and similarity of the scores for each factor and across the different statements, resulting in (average) counts for the paired-factor comparison section. Within the scope of this paper, this score can be used as an indicator to the perceived overall creativity and its factors.

### 3.2 Creativity support index results

*Table 1. CSI results for the rating scale and paired-factor comparison section*

| Creativity support factors | Factor scores related to the PSS toolbox in descending order of agreement | | Factor scores (relative importance for PSS design) corresponding paired-factor comparison counts | |
|---|---|---|---|---|
| | /20 | (based on two rating scales) | /5 | |
| Collaboration | 12,65 | | 1.75 | (low importance) |
| Exploration | 12,06 | | 4.34 | (more important than any other factor) |
| ResultsWorthEffort | 11,70 | | 2.79 | (moderate importance) |
| Expressiveness | 10,92 | | 2.60 | (moderate importance) |
| Enjoyment | 10,69 | | 0.99 | (low importance) |
| Immersion | 8,02 | | 2.52 | (moderate importance) |

The average participants' agreement on the factor '**Collaboration**' shows that the PSS toolbox enables the participants to share ideas, designs and work easily in team. However the paired-factor comparison for 'Collaboration' indicating that users see the factor as less important in creativity support in general.
In the rating scale section, the creativity support factor '**Exploration**' indicates that participants agree that the PSS toolbox provides the necessary support for creativity through different ideas, outcomes and possibilities. The rating scale factor score corresponds with the score it received in the paired-factor comparison section. This result is important because the creativity support factor 'Exploration' receives the highest paired-factor comparison count from the users, who chose this factor as more important than any other factor.
'**Results_Worth_Effort**' has a similar - but slightly lower - score than the previous creativity support factors. It shows that participants were satisfied with what they got out of the PSS toolbox. Correspondingly, the users find the amount of effort required for the same amount of work with the usage of tools in general, of moderate importance.
On '**Expressiveness**' participants were still satisfied with the outcome, but agree that the PSS toolbox provides only moderate support in their creativity. The paired-factor comparison shows a corresponding score, nonetheless users still search for something that better expresses their thoughts.
Participants score '**Enjoyment**' of the PSS toolbox as fairly moderate, but this is analog with the score in the paired-factor comparison section. The creativity support factor 'Enjoyment' received a visibly lower count and seems inferior to any other factor.
To close, the users were not satisfied with the way they were engaged in the use of the PSS toolbox. However, the creativity support factor '**Immersion**' gives a count of moderate importance, meaning that they want tool(s) to provide reasonable creativity support to users engaged in PSS design.
We asked all student groups to complete the CSI questionnaire on three moments during the project and usage of the toolbox. This allowed us to have a better consecutive view on the usage of the individual tools, templates and posters after the students used them in the design process. Figure 2 combines the agreement statements and the paired-factor comparison into CSI scores and gives an indication of the total creativity support. As the design process and the introduction of tools progresses, the CSI scores have an upward tendency. This allows us to reflect upon how well the toolbox and its individual tools support creativity for the particular task the design teams was engaged in or had to perform.

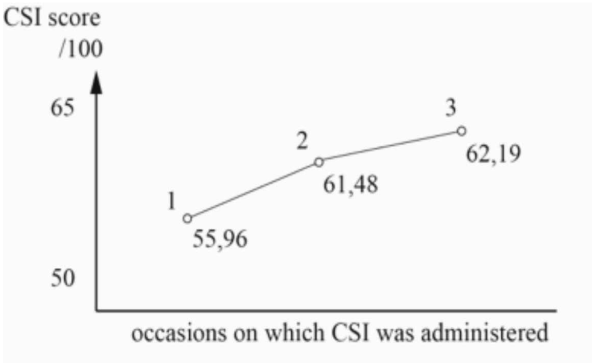
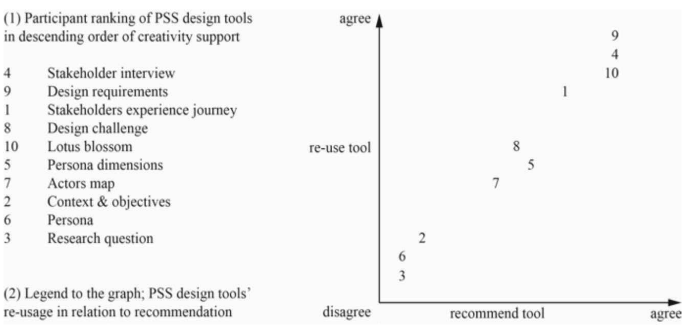



*Figure 2. CSI (total) scores*

### 3.3 The PSS tools in relation to creativity support

Table 2 provides a clear image on the participants view on the individual tools within the PSS toolbox, which are ranked in descending order of creativity support. Adjacent to the ranking - that also serves as legend - the graph represents a graphical ordering of the individual tools in terms of participant agreement on re-usage and recommendation to others. Besides an obvious correspondence between re-usage and recommendation, the participants follow a tendency to rank the PSS tools in a similar way.

*Table 2. PSS toolbox; ranking, re-use and recommendation*




## 4 DISCUSSION

The scores are dependent on both individual preferences, as well as the individual's level of expertise with each of the tools. Therefore we formed groups of three who filled out the questionnaire. As they had to discuss each answer in group, we were avoiding individual preferences. At the moment the project took place, the toolkit was not yet published. This gave us confidence that none of the participants had experience with the provided tools. Another type of expertise could also impact the results, namely the level of expertise in the domain. Again, individual differences should be averaged out since the groups all consisted of three first master students in product development with a similar educational background.

Where the design teams took the survey at three occasions, the results showed a slight increase in the total CSI score. We acknowledge that the results might be biased for following reasons:

1. Only nine of seventeen groups administered the CSI tool as required (some of the participants did not save the survey, did not fill out the whole survey, etc.) and on each of the three occasions.
2. The results might go up because of increased knowledge in the design and its process.
3. The toolbox' tools introduced during the later stages of the design process have a more tangible outcome, and could therefore provide higher creativity support scores.

An additional note that should be made is that a CSI score for a creativity support tool (the service design toolkit) is not necessarily representative of the whole CST. It reflects upon a CST being used during a particular task or activity, by a particular type of user.

## 5 CONCLUSIONS AND FUTURE RESEARCH

With regards to the creativity support factors, the PSS toolbox stimulates group dynamics and co-creation sessions with future users and potential service providers. Tools such as the Stakeholders experience journey (tool 1) and the Stakeholders interview (tool 4) prove their importance to the CSI factor 'Collaboration'. The uniform but open structure of the PSS toolbox demonstrated to be relevant for a wide range of design challenges in different domains (CSI factor: Exploration). E.g. the Lotus blossom (tool 10) showed to be more supportive in 'Exploration' than the Actors map (tool 7). Finally, higher ranked tools like the Design requirements (tool 9) and the Design challenge (tool 8) relate output and effort to the corresponding CSI factor 'Results_Worth_Effort'. The lower scores on the CSI factors 'Expressiveness', 'Enjoyment' and 'Immersion' indicate that it is not enough represented in the tool and provides room for improvement. The PSS toolbox may need to invest on ways to improve creativity and expressiveness with the tool and enhance the workflow and absorption in the activity to ensure that the tools are used on a more regular basis.

Besides creativity support, the PSS toolbox was evaluated on the specific goals of each tool. We specifically focused on what part(s) of the toolbox worked better than others and if steps or even specific tools were missing. In addition, we related the skills and design outcome of the project to the creativity support and evaluation of the toolbox to better prepare future generation designers for challenges that come with designing these product service systems. The findings of this additional research step still required further analysis in order to be fully compared to the research presented in this paper. Additional future research aims to test, validate and finally refine the PSS toolbox in an organizational context, with companies that are making the transition to integrate products and services.

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# CORPORATE COOPERATION IN DESIGN EDUCATION IN LIGHT OF SITUATED LEARNING

**Tore GULDEN and Bente SKJELBRED**
Oslo and Akershus University College of Applied Sciences

**ABSTRACT**
This paper explores how one can understand corporate cooperation as part of design education in the light of theory on situated learning. The origin for the study is a cooperative project between postgraduate students in Product Design and Lego. The students worked from a satellite office on campus on an open-innovation developing platform with Lego.
The suitability of problem-based learning and master-novice learning is compared to functioning in a community of practice and an open-innovation process, as most of the students have been subjected to these learning approaches in their former education.
The project presented some challenges to the students in relation to understanding their roles and assessing their performance. While reflecting on the project, the students recognized their limitations and suggested how the problems that arose could have been avoided.
As a consequence of this reflection, we suggest introducing cooperative projects on an open-innovation platform at the beginning of the BA rather than at the end of the MA. This would allow the student to comprehend his/her role as a designer and develop professional confidence earlier as well as to reach a higher level of understanding, cooperation and critical thinking. This opposed to learning by problem-based and master-novice pedagogical environments, which does not ensure the considering of the social relevance in design projects, acquisition of skills to perform in cross-functional teams, nor to equip students with the necessary skills to perform in a community of practice.

*Keywords: Situated learning, Open Innovation, Problem-based learning, Master-novice learning*

## 1 INTRODUCTION

The Product Design Education program at Oslo and Akershus University College of Applied Sciences (HIOA) has, as many other design education programs, much experience in running cooperative projects with industry players, a course-dimension believed to represent the *real world*. Since the inauguration of the master's program at HIOA in 2005, cooperation with external companies has been formalized in the study plan with a twelve-week, 20 ECTS weighted course in which students go to companies for practical placement.
The students attending have been previously exposed to both *individual* and *interactional pedagogical* views (see Figure 1) during their in-house BA study [1]. Hence, they have met both master-novice learning, which is based on knowledge- and skills transfer from one experienced person to several inexperienced others, and problem-based learning where students must choose the approach, skills, and methods, necessary in order to answer to the self-defined problem definition.
During the six first weeks of the second semester, some of the students complete the course Product Design, Psychology and Market (10 ECTS) working with Lego briefs. For the remaining twelve weeks of the semester, they complete their Practical Training (20 ECTS) with Lego from a satellite office at HIOA on an open-innovation (OI) developing platform with fellow students in other institutions and some designers at Lego. In this context, OI mostly represents an interactive organizational learning view, as teamwork is foremost in each project. Over the last two years, approximately one third of the master's students (15 in total) have completed this cooperative project with Lego.
Lego introduces a design brief at the beginning of the semester, which gives the students an understanding of the high expectations concerning work capacity and results. In order to motivate students and give them a clear understanding of what the project entails, they are invited to Billund to get insight into the development and production of the Lego toys. Accordingly, the students are

included in the design team at Billund, i.e., they get specific design briefs, regular tutoring, direction, and feedback from Lego.

During the course the students do engender concrete results and prototypes for testing and evaluation; nevertheless, the trend is that the design process lacks critical and conceptual thinking. Furthermore, the degree of creative self-efficacy, which can be explained as the belief in one's own ability to create, is low during the project [2].

This surprising trend inspired us to investigate possible underlying reasons through the research question, how can one understand corporate cooperation as a pedagogical learning environment in design education in the light of theory on situated learning?

## 2 METHOD

The empirical data in this study is based on student reports, interviews, and reflection notes from the two courses: Product Design, Psychology and Market (10 ECTS) and Practical Training (20 ECTS). The data analyzed is only from students who cooperated with Lego during these two courses.

We analyzed the empirical data via theories on situated learning and the four key terms coined by Etienne Wenger's [3] that explain *communities of practice* namely: Communities are not limited by formal structures, Address the tacit and dynamic aspects of knowledge, Links between learning and performance, Taking collective responsibility for managing the knowledge needed.

## 3 SITUATED LEARNING

Situated learning is concerned with everyday learning. Within this view, knowledge "is dynamically constructed as we conceive of what is happening to us" and, furthermore, our conception of our activity within a social network shapes how we think and act. [1] Accordingly, knowledge within situated learning is not an object, set of rules, facts, or descriptions, but rather a "capacity to coordinate and sequence behaviour to adapt to changing environments" [1] (see Figure 1, interactional view).

The situated learning view builds on Vygotskij's *zone of proximal development* (ZPD), i.e., that claim that students have more to gain through active participation in the learning experience. According to Vygotskij, ZPD is "the difference between what an individual can accomplish alone and the potential development through problem solving in collaboration with more capable peers." Accordingly, the "tools are the basis for carrying out the socially organized activity which, is, in turn, the basis for the development of new mental functioning and activity in the world." [4]

### 3.1 Communities of practice

The term *situated* does not refer to a physical place, rather a milieu where learning happens. These learning environments involve tools, methods, objects, and other factors, and possibly *capable peers*. Wenger refers to such learning environments as *communities of practice*. He states that knowledge is constructed while we live, act, and practice within a social network, influenced by one's own and others' activities. This stance resembles a social-constructivist worldview. [4-7] An action in this situation is controlled by a person's understanding of his or her place in a social process. [1]

Wenger describes practice as a "process, where we can experience the world and our engagement within it as meaningful." [3] Practitioners from a shared practice domain, who meet for discussions and activities out of sheer commitment, concern and interest, form communities of practice. In these communities they learn "how to do it better as they interact regularly." [8] Accordingly, communities of practice provide an active curriculum and a comprehensive learning environment in opposition to the traditional master-novice (MN) approach (see section 4.1). [1, 3] Lego serves as an example of a community of practice in the context at hand.

Wenger's characteristics of communities of practice partially make the categories for the analysis of the empirical data as follows:

- Communities of practice enable practitioners to *take collective responsibility for managing* the knowledge they need, recognizing that, given the proper structure, they are in the best position to do this
- Communities of practice create a direct *link between learning and performance*, because the same people participate in communities of practice as in teams and business units
- Practitioners can *address the tacit and dynamic aspects of knowledge* creation and sharing, as well as the more explicit aspects

Communities are *not limited by formal structures*: they create connections among people across organizational and geographic boundaries

| | Knowledge is about | Knowledge resides in | Knowledge developed by |
|---|---|---|---|
| **Individual view:** Reify individual employee, an constant player moving in the corporation | Technical details of products and services (internal capacity) | Specialized employees (stored in individual heads) | Training given to individual |
| **Interactional view:** Reify company-customer relations as stable & responsive | Customer relations (interactive capacity) | Cross-functional team (manifest in activity) | Project activity of functional work-group and teams |

*Figure 1. Two different epistemological approaches towards organizational learning (W. J. Clancey, 1995)*

## 4 ANALYSIS OF THE DIDACTICAL BASIS FOR THE PROJECT

The following section presents the different learning approaches that the students are exposed to during their education, namely problem-based learning (PBL), master-novice learning (MN), and the OI during the internship period.

### 4.1 The Master-novice learning approach

The traditional MN pedagogical view acknowledges that learning is the "reception of factual knowledge and information", where the master is the sole source for learning. [1, 3] Although we do not use this instructional system in our MA program, it is widely used during the first part of our BA program in Product Design. Typically, a professor would instruct the students via a demonstration about health, safety, and environmental activities associated with the use of the machine park, but also in the information on how to use specific techniques of production as part of a design process as well as in construction and design guidance. The MN learning approach compares to the individual view of learning (see Figure 1).

### 4.2 Problem based learning

PBL is used extensively on both our BA and MA programs. Although the students do not study the theoretical side of the PBL approach, they have experience with it through practice. The PBL approach is described by Walsh as "a pedagogical approach which uses cares and problems as a starting points for acquiring the desired learning objectives." [9]
PBL has been criticized for the various adulterated forms that emerge by subjective interpretations, dependency on large educator resources, feelings of frustration by the students, and questionable efficacy. [10]
The approach is mainly comparable with the interactional view (see Figure 1), but it can also be instructive in the sense that students can define what is relevant *cares* and *problems* on the basis of confined experiences and through influence by the tutor. Furthermore, there is no emphasis on the comprehension of the students' place in a social process as there is in the ZPD.

### 4.3 OI at Lego

Chesbrough describes OI as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and explain the market for external respectively. This paradigm assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advantage their technology." [11] The OI view rests on two kinds of understanding of the term "open". There is the "outside in", where a company makes greater use of external ideas and technologies, and the "inside out", where a company allows some of its own ideas, technologies, or processes to be used by other businesses. Chesbrough mentions Lego as "a striking example of "outside in" [11] innovation.
A different system for evaluating ideas has emerged in the outside-in openness scheme, namely the "wisdom of the crowd," [11] which was intensified in the Lego Group in 2004. Wisdom of crowd is a decision system where everyone involved in the process gets an equal amount of votes to use in the

selection of concepts, this to avoid self-interest to be a major reason for choice. Erik Legernes, senior creative director at Lego and contact person for the cooperation, believes in the wisdom of the crowd and stated that, “people who come from different disciplines provoke and challenge each other, which is a lot more fruitful than working with people who work the same way” [12].

# 5 DISCUSSION

## 5.1 Taking collective responsibility for managing the knowledge needed

As a general trend, the students enjoyed the OI process at Lego, which seemed to establish a safe working environment. As one student says,

> “Adults playing their way towards rough concept sketches accompanied with lots of laughter and fooling around was interesting. This is how I hoped and believed it would be. This work process opens for all kinds of wild ideas and nothing is too poor or silly to be presented.”2

However, when confronted with this process and the people involved, the students left their own processes behind to some extent. They gathered most of the necessary information through Lego. Typically, the students did not challenge or take responsibility for managing the knowledge needed. As one student said, “I’ve done what Lego wanted me to do, and it has not always been consistent with my personal learning goals.” Seemingly, the students did not work optimally with regard to representing themselves as challenging, capable peers. Furthermore, they had phases where they felt dispirited and not able to manage or understand their role in the network. This might have to do with problems in communication. As one student pointed out,

> “Challenges of communication occurred immediately with Billund [on Skype]…we did not see what they presented and we did not grasp everything that was said either, and after asking them to repeat several times it became embarrassing to ask for more repetitions, so we just let it pass. The result of this was that we became unsure of what we should be working with…and then we fell behind all the time.”

The students identified the communication problems, but, considering the level of frustration and impact on the quality of their work, the effort invested to solve the problem was insufficient. For example, the students did not establish a system for documenting the meetings with Lego. However, they did take an initiative towards communicating their concepts to Lego through video, which was somewhat successful.

## 5.2 Links between learning and performance

The students did not feel they had the necessary skills to function in and as a cross-functional team in the community of practice. In the meetings with the employer, they tried to grasp the essence of Lego’s instructions and requirements instead of exploring and searching for other methods, knowledge, and tools suitable for the project. Accordingly, feelings of self-efficacy were not strengthened during the project. On the contrary, the students felt incapable of working independently and waited for weekly guidance from Lego in order to continue their work.

After the project, however, a new understanding emerged. The students identified things they could have done differently. As one student noted,

> “I personally think that if we had taken the initiative and communicated the concepts that we really believed in, it would have given us a different kind of respect in relation to what we can offer. We were interested in the projects, but sometimes we just kept things to ourselves and stayed within the framework we were given.”

Accordingly, in hindsight they identified that they lacked the understanding of the role they had in the community of practice and, furthermore, the lack of managing the necessary knowledge and learning in order to perform differently from any in-house team.

The students certainly felt that they learned the business side of design through the OI process. As one student said, “It has been an interesting process that has given me a wider understanding of how such an enormous corporate group works, and how one has to communicate in order to be heard.” Furthermore, they recognized the importance of the quality of presentation within the scheme of wisdom of the crowd. As one student pointed out, in order to communicate an idea throughout the vast network within Lego, “a good idea is not better than the effort given at a presentation.”

The students acknowledged the advantages and disadvantages of the OI process and found it demanding and rewarding. The process of working in groups across institutions was successful.

Curiously, it seems that the work across institutions worked better than among the students locally. As one student pointed out, "During some phases we spoke very little to each other and kept working *by ourselves*" and "none of the final concepts that we created were developed by only one person alone, it was always group work." Accordingly, it seems that even though they had problems working together, they managed to work in the OI community of practice.

### 5.3 Address the tacit and dynamic aspects of knowledge

The students made several models and prototypes. Curiously, they did not make use of the traditional laboratories where they normally make mock-ups and models; instead, they used existing Lego bricks or rapid prototyping, even though their reification skills mainly lie within manual work and not CAD. This may have been the case because they believed this was what was expected of them, as it is the process most often used by Lego. Accordingly, they developed very few concepts. Lego valued some of their concepts, but the low production and scant variation surprised the tutors and people involved.

### 5.4 Communities are not limited by formal structures

The students tested out concepts at the local primary school (a cooperation project established by the teachers). The students found this evaluation process fruitful, as one student mentioned, "I have learned a lot about the involvement of users as a part of the design process, and I see the value of testing out concepts on children."

Apart from this external activity, the students did not make any contact with external people in order to gain or map possible necessary knowledge during the project. Accordingly, no diverse community of capable peers was created and, consequently, no dynamic curriculum was developed beyond the one presented by the Lego group.

### 5.5 Learning in relation to PBL, MN, and OI

The aim of the PBL approach is to instil the skills of independent, critical, and holistic thinking. The students' experiences with OI incited some critical thoughts about PBL, OI, and the instructive dimension at Lego, as the following statement illustrates:

> "I like the workshop style of the Lego process. It is really effective. If you have an idea…instead of sitting at your desk for five hours drawing, you just directly build it. In school, it is more of a slow process because what we learn here is somewhat different. When we went to Lego, we were kind of surprised about the way they do things...in a better way."

Counter to being critical, the students were perhaps too fond and respectful of their supervisor at Lego in relation to learning and performance. As one student put it:

> "It was not necessarily what our supervisor said…as information that gave us insight to his and Lego's thoughts…but his questions and his immediate reaction during our presentation of concepts and models. They signalled a clear direction that the process should take. This had great value since we often have a 'too open approach' during our work with school projects, and in addition we don't have the same strict demands on the products."

Obviously, the full meaning of PBL had not been conveyed to the students. What they do see is that PBL can result in passivity rather than action and exploration as experienced with Lego and OI.

During the cooperation project, the students had access to knowledge available through open cross-disciplinary processes. Furthermore, Lego made it very clear that they evaluate concepts according to the wisdom of the crowd principle. Even though students sometimes felt like they were working alone, they also noted that no concept was developed by one person alone. On the contrary, the concepts were based on the curriculum of the capable peers and directed in a specific direction by the crowd.

In contrast to the OI, it is easy to execute the PBL approach without a dynamic curriculum defined by capable peers in a community of practice. Moreover, teachers influence the students' choices and hypotheses and confine the workspace by coincidental knowledge transfer, subjectivity, and ideology. Furthermore, students' interests also represent knowledge and experiences that are not necessarily representative of the current or future society. The knowledge, skills, and general competence that the students achieve through using this instructional system might therefore cause a gap in a more complex community of practice in terms of corporate cooperation and, in this case, OI. As one student notes, "I have learned that in real life projects, there are many more factors to evaluate, and changes may and will come. We, as designers, have to be prepared for these changes and open to taking new challenges." The above-criticized facets of PBL compares to the MN learning approach and the individual pedagogical learning view (see figure 1).

## 6 FINAL REMARKS

The students did not feel they performed at their best during the cooperation project; rather they felt insecure and to some extent only did what they were told. Thus, it seems that they were not equipped to perform in a community of practice. Accordingly, one can say that the students had a limited understanding of their role in the social network that the cooperation constituted during the project. However, in the reflection notes, some students mentioned that they were aware that this was the case. Thus, the encounter with the community of practice at Lego made the students reflect on their own situation in relation to learning and performance in retrospect. Moreover, the students consider understanding, cooperation and critical thinking to be a competence. In a community of design practice, such competence would seem elementary.

It is therefore natural to assume that by giving students the chance to obtain such *basic* competence by introducing OI cooperation at the beginning of a BA rather than at the end of a MA education, they would obtain a comprehension of their own role as a designer and consequently their professional confidence will develop earlier. In this context, the role of the educator shifts from being a limited and subjective source of information to a facilitator for learning in practice. The industry, as a community of practice would then serve as a multifaceted environment and additional source for the consideration of a project's social relevance. The possible sharing of experiences among students during such a project, would serve to prevent the instruction of what relevant *cares* and *problems* might be, from the educator and industry. The demands of performance in an OI project will also contribute to the discussion of what basic design skills might be, as in the example in this paper, students were trained to perform in traditional material workshops and asked to perform in a milieu were ideation, cooperation, concept development, communication and networking are considered most important.

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## Chapter 2

# USING TECHNOLOGY IN TEACHING

# INTRODUCING THE LOGCAL: TEMPLATE-BASED DOCUMENTATION SUPPORT FOR EDUCATIONAL DESIGN THINKING PROJECTS

**Axel MENNING[1], Thomas BEYHL[2], Holger GIESE[2], Ulrich WEINBERG[1] and Claudia NICOLAI[1]**
[1]Hasso Plattner Institute for IT Systems Engineering, School of Design Thinking
[2]Hasso Plattner Institute for IT Systems Engineering, System Analysis and Modelling

**ABSTRACT**
Design Thinking (DT) has proven to be a solid approach to engage in complex and ill-defined problem scenarios. Still, Design Documentation (DD) is a complex and yet essential part of the DT process itself. The setting of DT and it's modes of information treatment strongly affect the documentation behaviour and distinguish it from other domains of documentation. In this paper, we will define DD as a part of design ability and, therefore, as task and driver within the design process. In order to set a frame for analytical and intuitive documentation activities, we propose a model of DD and differentiate three DD purposes: 1) capture and retrieve Design Rationale (DR), 2) support reflection, as well as 3) compile and communicate DR. Based on this definition, we introduce a template-based documentation tool (LogCal), which supports the DD performance. In a controlled experiment we handed out the LogCal as a cultural probe to 16 design teams at the HPI School of Design Thinking. By analyzing the experimental data set and evaluation sheets, we investigate the documentation behaviour of design teams as well as the ability of the LogCal to support design documentation. These results lead to hypotheses concerning the application of template-based DD tools and its structure.

*Keywords: Design Thinking, Design Rationale, Design Research, Knowledge Management, Design Documentation*

## 1 INTRODUCTION

Design Thinking (DT) has proven to be a solid approach to engage in complex and ill-defined problem scenarios. The attributes of DT are interdisciplinary teamwork, creative team spaces and an iterative design process model. Throughout the whole design process teams have to cope with ill-defined information in different ways. Information treatment in DT can generally be distinguished into two different modes [1]:

- **Dualistic mode of exploration:** Since *"a design problem keeps changing while it is treated"* [2], Design teams iteratively explore the problem and solution space in the mode of an ongoing "conversation" [3].
- **Divergence and convergence:** DT teams are required to approach a design problem by generating variety (diverging) and reducing variety (converging) of information.

To confidently process and explore information within both modes, can be considered as fundamentals of *design ability* [4]. In this paper, we set and define the purposes of Design Documentation (DD) within the context of both modes of information treatment. Based on our definition, we introduce our DD tool (LogCal), which supports students at the HPI School of Design Thinking to better capture and retrieve their Design Rationale (DR) in order to improve the design phases and handover process.
This paper is structured as follows. In Sec. 2 we discuss existing documentation approaches and tools. Afterwards, in Sec. 3 we define the purposes of DD, before we introduce our LogCal in Sec. 4. In Sec. 5 we evaluate the LogCal with respect to our purposes of DD. We outline future work in Sec. 6.

## 2 RELATED WORK

Many studies, especially in the field of design research, human computer interaction, software architecture research and artificial intelligence have been dedicated to the development and

improvement of DR Systems. Kunz et al. [5] introduced the basic model of DR. They observed ill-defined problem situations (cf. wicked problems) and characterized, that problem definitions continuously shift. They conclude that, *"there are no logical or epistemological constraints or rules that would prescribe which of the various meaningful steps to take next"* [2]. In order to still be able to guide and communicate the design process and the inherent DR, they pleaded for an argumentation-based approach and introduced the DR system IBIS (Issue Based Information System). Schön observed professional workers, who were dealing with ill-defined problems [6]. He identifies professional artistry as an alternative epistemological model. The core of his theory of reflective practice is to immediately reflect on tacitly motivated actions, as *"our knowing is in our action"* [6]. Dalsgaard et al. implemented Schön's approach of *reflection in action* into a software system called PRT (Project Reflection Tool). *"Documentation may serve the double role of supporting reflection, thereby serving as a source of insight, and providing evidence that supports the insight gained"* [7]. In the context of lean management methods, the Toyota Motor Corporation developed and applied a template-based status report method. It is called A3 and it is used to give status reports during production processes and to treat issues. A3 reports follow a PDCA cycle (Plan–Do–Check–Act) [8], which is applicable to all issues within a production system.
Beyhl et al. discussed *"why innovation processes need to support traceability"* [9] and propose a digital documentation tool based on a whiteboard metaphor [10]. Their documentation tool captures the information created by design teams from several other sources, e.g. file storages, and enables the design teams to set information into relation by arranging artifacts on a digital whiteboard [11].

## 3 DESIGN DOCUMENTATION

In this section we define DD in the context of Design Thinking (Sec. 3.1), describe the purposes of Design Documentation (Sec. 3.2), and compare both issues with respect to related work (Sec. 3.3).

### 3.1 Definition of Design Documentation

We observed that the term "documentation" is frequently used in DT projects and design related academic publications, but has a broad meaning and describes different things. It is often used as an umbrella word for capturing information, like note taking or video recording or it is used as a synonym for compiling captured information to a handover document. We consider both descriptions as activities of DD, but they are not sufficient to frame the whole capacity of DD. With reference to the mentioned modes of information treatment [1] we position DD as part of design ability and propose a new model of what DD is and does.
The DT process is an iterative process [12] and designers are frequently sampling the problem space with solution space and vice versa. This state requires to repetitively working with information and methods. A process integrated DD enables teams to retrieve information of an explicit and traceable design path. Therefore, DD contributes to the dualistic mode of exploration. Referring to the second mode of information treatment, to synthesize information requires overview and a shared understanding of a certain situation. In order to focus, it is essential to fade out information, but not to forget them. DD serves as a valve to hold back information that is not immediately relevant, but retain the ability to recover information when necessary. A process integrated DD enables teams to feed and retrieve information into an explicit and traceable way. Thereby, DD contributes to divergence and convergence.
The performance of DD is depending on analytical and intuitive activities. At first, DD is a rational reaction to the uncertainty designer's encounter. They leave traces for the reason of orientation, while exploring unknown grounds. Ideally teams capture decisions and their reasoning. But if teams have tacitly come up with decisions by acting or trying them out, they need reflective practice as a DD activity. Also the decision of what to capture (e.g. importance rating) and retrieve (e.g. affiliation inference) may depend on intuition. It is the designers' freedom, how logically or intuitively they assess, estimate, rate and cluster information. DD is part of design ability, because it requires intuitive and analytical actions as well as it is consequently interwoven with the design process.
To support DD is particular important in educational contexts, since students need to gradually build up confidence and experience with DD.

### 3.2 Purpose of Design Documentation

Fig. 1 depicts the purpose model of DD in the temporal relationship of design phase, design process and handover process. The design phase is a part of the design process in which teams follow a certain mode (e.g. observation, ideation, prototyping) to narrow down and solve the design challenge. The handover process deals with the preparation of a handover document that helps, e.g. clients, to recover the design path and understand design decisions.

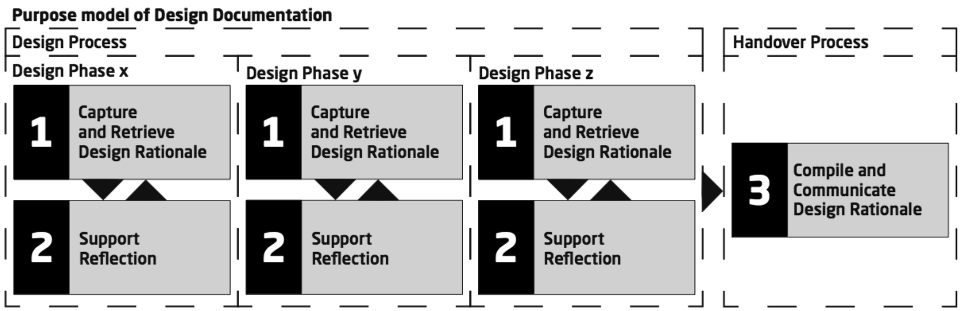


*Figure 1. Purpose model of Design Documentation*

#### *3.2.1 Capture and Retrieve Design Rationale (P1)*

Purpose one frames the DD activities DR capture and DR retrieval. P1 enables verification, evaluation, and reuse of information as well as the detection of conflicts among new requirements and old decisions. Furthermore, it is a source of inspiration and enables overview.

#### *3.2.2 Support Reflection (P2)*

Purpose two frames the DD activity of immediate reflection on the captured content. The capture and retrieval (P1) of design reasons may depend on reflective practice. Altogether, P1 and P2 are continuous interwoven activities within the design process.

#### *3.2.3 Compile and Communicate Design Rationale (P3)*

Purpose three supports communication and enables the compilation of design decisions and the underlying reasoning. Purpose three is informed by purpose P1 and P2.

### 3.3 Discussion

DD is a constant mode throughout the design process and handover process. DD enhances the process as it builds on and triggers design methods. DD activities are DR capture, retrieval, compiling and communication. However, it might not be possible without implementing reflective practice, because the reflection on captured decisions may unveil the designers reasoning. Fig. 1 distinguishes DD into three purposes. It enables a better understanding of the relation between different DD activities and depicts the emphasis of DD as part of the design process. Our model illustrates as well the interdependency between information capture and the loop of immediate reflection, i.e. reflection in action [6]. *„Practitioners apply tacit knowledge-in-action, and when their messy problems do not yield to it, they do not take 'time out' to reflect. […] Instead, they 'reflect-in-action, […]"* [13]. We follow Dalsgaard's approach [7] to integrate reflective practice into the documentation process. Since DD activities during the rather unstable design process are carried out in rational and artistic means, P1 and P2 can be seen as representations of both modes. While the handover process is a rather stable mode of communication. DD enables traceability and, therefore, downsizes the distance between the designer's image of the idea and the stakeholder's image of the idea. Handover documents can be compiled based on the information captured when practicing P1 and P2 frequently throughout the design process. The model illustrates how the centre of DD activities are weighted within the design process.

## 4 INTRODUCTION TO THE LOGCAL

As each design team creates a unique design path, DD tools have to be (a) applicable to this uniqueness. Therefore, the general structure of the DD tool has to be compatible with arbitrary design paths and design phases within a certain temporal structure. But at the same time, the DD tool should ask questions that are specific enough to decompose design phases. Therefore, (b) the frequency in which DD tools ask questions has to fit to the designers' process. A lot of DT work is done on whiteboards and sticky notes as these materials support a shared understanding. Thus, (c) DD tools have to fit in this environmental setting and should support low-barrier integration of diverse artifact formats regarding the certain design phase (e.g. sticky notes, sketches, texts, and pictures). In fact, DD tools have to become DT artifacts themselves in order to create the DD as interplay of the whole team along the process. The LogCal (logbook & calendar) is a template-based documentation framework of open-ended questions. This A3 sheet allows Design Thinking teams to simply drag and drop content from the whiteboard into blank fields of the LogCal or to develop new information directly within the blank fields of the LogCal, e.g. by sketching. The chronological framework follows the general DT process and encodes decisions in a chronological order. The temporal unity of the LogCal is one day and the main section of the LogCal follows the PDCA cycle. Therefore, one template covers several issues that need to be answered and can be applied to any design phase and works independent regarding a project time frame. The iterative documentation cycle enables continuity and the explicit creation of a design path.

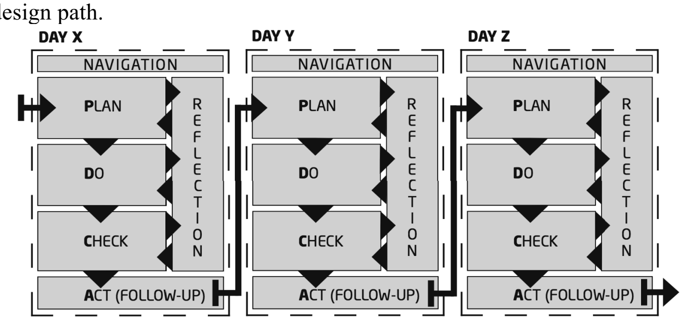


*Figure 2. LogCal scheme with embedded PDCA cycle*

As depicted by Fig. 2 each template has the same general structure and consists of a header and two parts - a chronological framework and a reflection part. The *NAVIGATION* field in the header of the LogCal provides information to recover temporal design paths. It contains blank fields for team name, the current design phase, number of day, and a quick response (QR) code that identifies the LogCal page for post-processing purposes. The main section provides blank fields for documentation in terms of a PDCA-cycle [8]. The *PLAN* field is dedicated to formulate and sketch the preparation of the activities that are performed as described within the *DO* field. The *CHECK* field captures the results of the performed actions. The *REFLECTION* field captures the meaning of the *PLAN*-, *DO*- and *CHECK*-information as well as their relation and influence to the overall challenge. The *ACT* field is based on the upper information and is dedicated for describing next steps. It builds the transition to the planning section of the next day.

## 5 EXPERIMENT SET UP AND EVALUATION

In this section we evaluate the performance of the LogCal as template-based documentation support. In Sec. 5.1 we describe the general evaluation setting. In Sec. 5.2 we analyze filled out LogCals and evaluate our LogCal survey. We interpret the results concerning the DD purposes in Sec. 5.4.

### 5.1 Setting

As templates like the LogCal have not been tested before to assess their DD performance, an experiment was set up. The LogCal was distributed to 16 student teams (4-5 students per team) during the winter term 2013/14 at the HPI School of Design Thinking. Over the duration of 12 working days the students ran through a full DT-cycle and had three extra days for iteration and preparation of a final presentation. Thereby, eight different design challenges existed and two student teams tackled each design challenge simultaneously. It was recommended to the teams to integrate the LogCal collaboratively into the design phase. Prior, the students gained DT experience by attending DT projects of four working days and six working days.

### 5.2 LogCal Analysis Based On Grounded Theory

From a researchers perspective the LogCal functions as a qualitative diary study format. We treat the LogCals as cultural probes [14] for designers. As studies on template-based DD have not been published so far, verification of the received data is impossible. Thus, we analyze the received data set based on grounded theory [15] and derive new hypotheses on DD behaviour of students by studying the results. As depicted by the box plot on the left hand side of Fig. 3 the results show that 72,5 % (Min: 37,5%, Max: 100%) of template fields were used for information capture. The box plot in the middle of Fig. 3 depicts an average use of 64,76% of text (min.: 35,58%, max.: 80,0%), 32,04% of sketches (min.: 16,87%, max.: 61,29%) and 3,20% (min.: 0,0%, max.: 10,0%) of reused artifacts such as post-its taken from the whiteboard and pasted to blank fields of the LogCal. The bar chart depicted in the middle of Fig. 3 shows the artifact usage per design team. The majority of the design teams used text to fill out the LogCal and used sketches to visualize their ideas and concepts. Team six constitutes an exception to the general observation, since this team used more sketches (61,29%) than text (35,48%).

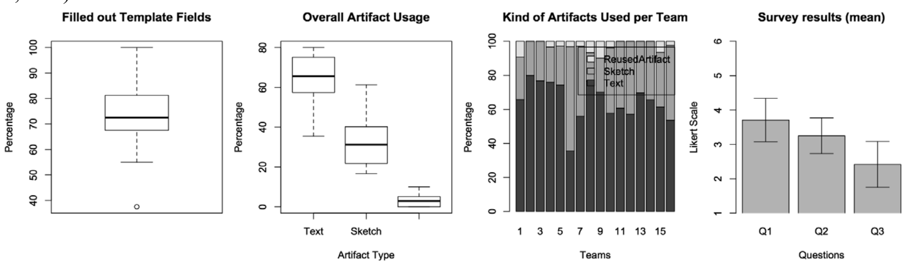


*Figure 3. Left: Filled out template fields; Middle: General artifact usage; Right: Survey results*

We conducted a survey to assess the usage of the LogCal regarding the purposes of DD. We asked the students, who participated and used the LogCal in the DT project, to rate the following question statements using a Likert scale from 1 (strongly agree) to 6 (strongly disagree). 24 of 80 students answered the following questions:

- Q1: *My team and me used the LogCal to retrieve information during our design process.*
- Q2: *The LogCal helped my team and me to reflect on design methods we applied.*
- Q3: *The LogCal helps my team and me to create a final documentation.*

As Fig. 3 depicts on the right hand side, the results of questions Q1 (arithmetic mean x=3,71) and Q2 (x=3,25) are balanced, while the results of question Q3 (x=2,42) can be perceived as positive result in terms of P3.

### 5.3 Interpretation of Data And Deduction Of Hypotheses

The following hypotheses are results of comparing the DD definition with the qualitative evaluation of the LogCals.

#### *5.3.1 Template-Based DD Tools Are Not Restraining Visual Expression (H1)*

Analogue and template-based documentation tools have potential to support DD, since 72,5 % of all template fields have been filled out. Furthermore, the PDCA structure is useful to separate dedicated design phase fields and dedicated reflection fields, which supports DD P3 as well. The template fields were used with 32,04% of sketches. Thus, we hypothesize that template-based DD tools are not restraining visual expression within DD P1 and P2.

#### *5.3.2 Template-Based DD Tools Improve Traceability of Design Paths (H2)*

The analysis of Q3 shows that a template-based documentation tool like the LogCal supports the students in creating handover documents. However, how well the design path is traceable for persons, who are not familiar with the design project, has to be further explored. We hypothesize that template-based DD tools improve traceability of design paths.

#### *5.3.3 Instant Touch Points For DD Tools Improve Design Phases (H3)*

The frequent information retrieval from a documentation tool enables inspiration, verification of insights, and detection of conflicts among new requirements and old decisions. When comparing the importance of DD with the results of Q1 (x=3,71), it is necessary to increase the number of touch points of design activities with the LogCal. We hypothesize that more touch points between design teams and documentation tools will improve design phases.

### 5.4 Threats to Validity

Our data set covers a variety of different design challenges and a large amount of interdisciplinary students with different design skills. However, the functionality of the LogCal has been only tested within the specific Design Thinking context. Only 24 of 80 students participated in our survey, which leads to a limited significance of the results. Further, the validity of collaborative aspects of the LogCal is not guaranteed, because the student teams were responsible to organize DD. Regarding the captured data we have not focused on a quantitative analysis of words, sketches and reused artifacts per template field. This means our analysis is only valid for the whole LogCal sheet and we can make no valid conclusions concerning the impact of the PDCA-cycle and reflective practice. Further, we are not able to evaluate the correctness and relevance of the answers to question made by the LogCal. In this article the LogCal analysis only represents the student's point of view.

## 6 FUTURE WORK

The LogCal in its first stage captures the design process and communicates the challenges, ideas, and final outcomes. Further proceedings in the development of the LogCal will mainly cover two different areas. First, we want to improve the impact of DD on the design process itself. Secondly, we want to level up the LogCal to a semi-formal approach to enable computer readability and automatic post-processing, e.g. enable an automatic querying as well as question-based completion of captured information. The applicability of such template-based structures will be tested in similar fields of design education and design work.

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# ELEARNING AND EMAKING IN PRODUCT DESIGN EDUCATION

**Jennifer LOY**
Griffith University

**ABSTRACT**
Creating proactive learners in design education requires inspiring students to think for themselves, to look beyond the classroom and see the opportunities and challenges in the outside world. As blended learning becomes part of design education, a rise in digital technologies allows an innovative thinking approach to eLearning that includes eMaking. This has the potential to have a transformative effect on learning, making it possible to move to a more collaborative form of learning as students and lecturers explore the possibilities of new technologies together, supporting a change in the relationship of students to lecturers, and a change in attitude to the way students see themselves and their own learning.
This paper describes an example of how an open approach to technology in the classroom, supporting eLearning and eMaking, contributes to the personal and professional development of design students and develops the role of the lecturer in response to current thinking in learning and teaching in higher education.

*Keywords: 3D printing, eLearning, digital technologies, eMaking, studio*

## 1 INTRODUCTION

The term eLearning no longer refers to content uploaded onto a server for student access outside the lectures, instead eLearning covers a complex range of interactive learning activities that cross over between classroom, lecture and self directed learning to support the overall student experience. The interaction between learning online and offline is becoming seamless in a combined digital and physical learning environment, as laptops and internet enabled phones make computer-based learning mobile, invading the classroom to support on the spot fact-checking and directed research as well as the recording of activity research and inspiration gathering. For Product Design education, eLearning is changing how students learn, what is brought into the classroom, and more importantly, the relationship of the students to their learning and the role of the lecturer. Even beyond that, eLearning in its fullest interpretation of the term - as placing student learning and the organisation of learning within a global environment enabled by digital communication - changes the relationship of the student to the world, projects to the complexities beyond the classroom, the lecturer to peers and the program to collaboration.
Just as eLearning, in its broadest sense, is breaking down the barriers between learning within individual educational institutions and the global community, so too, within design process education, eMaking as part of an eLearning strategy is breaking down barriers that have developed in Product Design education between the digital and the physical. eMaking [1] refers to the linking of digital making in the studio to a broader approach to digitally based learning. It includes all computer numerically controlled forms of making, such as laser cutting and CNC routering as well as 3D printing, and places them within an eLearning strategy that brings together online, on screen and in classroom learning that uses technology to reconnect the design process and operate within the current context of a web of electronic communication devices, networks and applications.

## 2 SUPPORTING AN ITERATIVE DESIGN PROCESS

At its most basic, digital making tools, such as 3D printing and CNC routering, enable students to produce a physical model of a concept that is dependent on their ability to computer model in three dimensions on screen, as opposed to their ability to manipulate physical materials in a conventional model making workshop. This changes the relationship of the student both to their computer work and to physical model making. For students coming into higher education more familiar with the virtual environment than the practical, 3D printing, at its most fundamental, helps to develop a connection between screen and reality, and rather than add to the disconnect between students and workshop practice, this has been found to provide a bridge between computer modelling and practical making that supports iterative project work [2].

This is significant, as one of the issues for applied design subjects taught in higher education in recent years, including Architecture and Industrial Design, has been the erosion of traditional studio practice [3] through the division of programs into modules to fit with the way other subjects are taught at university and space is organised and booked. Design process has been fragmented into a design studio practice limited to drawing and cardboard modelling, with a separate workshop practice and separate computer modelling courses run as parallel modules. The subjects are then taught in very different spaces and usually treated as separate for assessment until the final year of study when they come together in major project work. In some universities, workshops are becoming less accessible for the exploration of materials, structures and processes, and even for design development, and restricted to a role in final project outcomes in a documentation process, rather than as a developmental tool. This can be particularly the case for the larger first year cohorts, and this distances students from making as part of their process in the most formative part of their study. It is in the first year where design process is introduced and practices inculcated in the student and the culture of the discipline established, to be built on for the rest of the degree. As designing is an iterative process, students need to learn to explore and develop their ideas through research, drawing and studio model making as a whole right from the first year and that includes computer based modelling as a design tool, not as the documentation tool it used to be - computer based modelling needs to be integrated into design process and studio learning as much as the other design development tools [4].

### 2.1 Organisation of space

The first year 3D design studio at Griffith University has been reorganized to respond to the concept of eMaking as part of a broader eLearning strategy. At its most basic, the approach aimed to reconnect studio, CAD and workshop, with assessments running across modules and the physical space organized into group working pods, called ‘digipods’, that provide workspace for drawing and studio model making in amongst high end computer modelling software and digital fabrication technologies, in particular 3D printers for everyday use.

*Figure 1. Organisation of space into ‘digipods’ where students can work iteratively between screen, conventional design studio practice and prototyping*

The workspace meets the needs of those designing now so group work and Internet based communication are essential and constant access to resources on the web and online learning content is a practical requirement. Ramsden suggests that, “a focus on collaborative, supportive and purposeful leadership for teaching is associated with a culture of strong teamwork and student-focused approaches” [5]. By creating studio table space and floor space around the idea of a ‘digital pod’ students can work seamlessly between group discussion, drawing, digital recording and documentation of process, sketch modelling, online research, computer modelling, and digital fabrication, in an iterative learning cycle that moves their design thinking forward with more self determination. This new form of digital design studio places the student very much in the centre of their own learning with the facilities to work iteratively both on their own designs and in groups.

# 3 STUDENT CENTRED LEARNING

## 3.1 Connecting to learning

At the centre of bringing an eMaking strategy into the Product Design studio, is the lecturer relinquishing control in the classroom to allow the student a greater level of empowerment, as advocated in Weimer's book: Learner-Centred Teaching [6]. This is not solely focussed on the practical aspects of model making in the classroom, or even its role in integrating design process, but rather that new classroom strategies maximise the current worldwide developments to create essentially 'flipped' classrooms through eMaking as part of an open eLearning strategy that changes the relationship between the student and their own learning. It also changes the relationship of the lecturer to the learning experience, with the shared experience of exploring rapidly changing 3D printing developments on the Internet that are new to the lecturers and the students potentially reinvigorating the studios. This could contribute to addressing a sense of disconnection experienced between some students and lecturers that Race identifies as a reason for student attrition in the first year of University [7]. It could also potentially improve lecturer morale as educational research into relinquishing control in the classroom with courses developed formatively through collaboration between lecturers and students has shown that there are benefits for both from the unpredictability of the experience. For the lecturer, abandoning 'flight mode' for phones, iPads, and laptops and instead actively encouraging students to use electronic devices to check references live during a lecture, or allowing time for students to find related references during a discussion, as well as using active web sites over powerpoint slides does require confidence and a willingness to allow preplanning to be derailed by the students themselves, but the result can be a motivated student cohort and stimulating learning environment.

### *3.1.1 Flipped classrooms in design learning*

This strategy is arguably more important for students studying design subjects than for many other subjects, as the very nature of their work on graduation involves directing new practice. Graduate attributes for designers need to include the ability to direct their own learning for the lifelong learning approach that will be necessary for them to keep up with developments in their profession, and to manage their own learning with skills in mapping, researching information, dissemination and the application of new knowledge to design development tasks.

A 'flipped classroom' approach is a form of blended learning, where students research a topic in their own time, then the time within the classrooms for synthesis, rather than lecturer led dissemination [8]. However, unlike conventional flipped classroom learning, where the lecturer provides material on the university server for the student to download and study prior to coming to the classroom, in this scenario the student provides the study material and brings it to the classroom to share with peers and the lecturer – and 3D printing is a particularly useful tool in supporting this change of practice for Product Design education at the moment. This is for two reasons. The first is that 3D printing is creating such an impact across a myriad of applications that information is coming in too fast for a lecturer to keep up, meaning that a student is well positioned to be able to bring new information to the class, which is an empowering experience and the second is because the development of web 2.0 over the last ten years has led to an interactive networking system that is constantly refreshed that the digital natives (referring to those born after the spread of the internet around 1995) are very well versed at operating within.

Design graduates will work on projects that by their very definition are new each time. Creating proactive learners who base their work on researched information and considered opinions is essential for the discipline. Introducing 3D printing into the studio significantly contributes to this (at this time) if the lecturer fosters a broad eLearning approach, encouraging online research, interaction, and discussion. Formerly information around the study of a particular technology was researched and organized by the lecturer and the studio was based on the resources and research directions the lecturer provided. Because of this, the lecturer would be familiar with all the information and resources and have chosen what to include and what to exclude. This meant that student questions could largely be anticipated and prepared for. As the discipline is an applied one, many Product Design lecturers have an industry background in the design of commercial products for mass production, using conventional technologies such as injection moulding, that they can draw on in any classroom situation. They bring to their role the accumulated knowledge of their industry experience, their own learning experiences – predominantly studio based project learning – and accepted conventions for designing for production practices that have been building since the industrial revolution. However, whereas previous technologies added an additional chapter to previous practice, 3D printing is forcing a rewrite of the entire designers manual. Experience in a previous technology does not, in this case, inform practice in this one, and the underlying principles for mass production and business practice do not apply. For most lecturers, their professional development in response to additive manufacturing technologies is happening alongside the students' learning. There are only a few authoritative publications on 3D printing and its broader implications, such as Gibson et al [9], Anderson [10] and Gershenfeld [11], whilst the pace of change in industry and research at this time, taking printing into metals and polymers in applications as diverse as aeronautical and watchmaking, mean that the lecturer has to strive alongside the student to keep up to date. The reality is that the impact of the technologies across the board means that no single lecturer at this time can maintain an expert status in all applications, from medical to architecture and it is therefore more effective for learning on the subject for lecturers to encourage students to extend their learning outside the classroom and report back. This changes in the student/lecturer relationship with the students providing information as much, if not more, than the lecturer. Because of this, the lecturer will often be meeting the topic for the first time during the class, along with the other students – questions cannot be vetted, subjects that might have been steered around are difficult to avoid, conflicting reports will need to be challenged and discussed in class. For this to work, the lecturer has to be willing to change roles from leader to mentor / facilitator. The student is more likely to develop an attitude towards self-education conducive to lifelong learning, considering the lecturer a mentor rather than leader. An additional potential benefit of this approach is the lecturer can be as stimulated by the learning activities as the student, with the relationship between students and the lecturer positively affected by the shared experience that Race encourages lecturers to foster [12].

### 3.2 Connecting to the global environment

As much as the role of the lecturer moves towards that of a mentor as students bring knowledge into the classroom, so it can be moved further by the lecturer embracing additional Internet based opportunities to provide the Product Design student with feedback form external sources. For example, students working with 3D printing can be encouraged to upload their designs to an online service provider, such as iMaterialise or Shapeways, to test their designs for prototyping independent of the lecturer. The print needs to work within the constraints of the appropriate additive manufacturing technology, the material choice and the design (clearance etc), or the print will be rejected, as shown in Figure where the wall thickness in the seams of the model were insufficient.

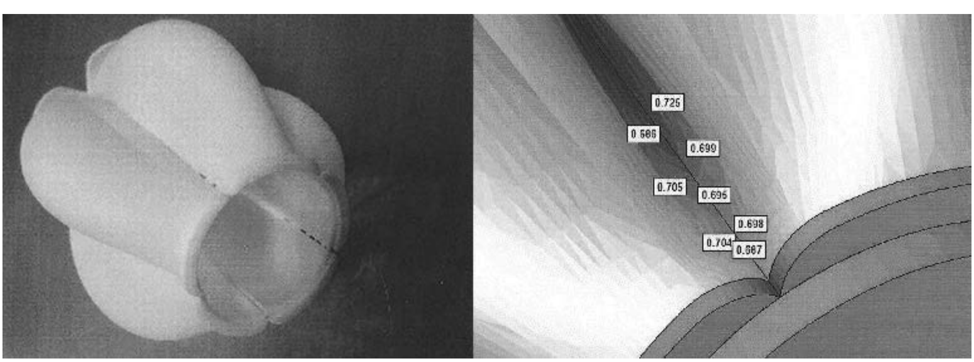


*Figure 2. Print failure report from Shapeways showing insufficient wall thickness in the seams*

The student can refine the data and resubmit, independent of the lecturer. This significantly changes the relationship of the student to the lecturer and to their own learning as the student learns about the constraints or advantages for their own design before the lecturer. If the part file fails, the student gets that feedback from an external source and works with the lecturer to fix the problem, rather than submitting to the lecturer for assessment.

In addition to external, practical feedback, the study of 3D printing takes student learning outside the studio and into the global digital environment, opening up learning opportunities that contribute to changing the student's perspective. For example, 3D printing provides a new starting point for addressing the current sustainability imperative if it is considered in relation to moving from mass production to mass customization and distributed manufacturing. Hugh Aldersley-Williams, in the RSA 'The New Tin Ear: Manufacturing, Materials and the Rise of the User-Maker', described the industrial revolution as a 'temporary interlude' to be replaced by mass customisation through 3D printing [13], which provides an interesting teaching tool for Product Design as, if it happens, all products will need to be redesigned for the new production methods and, with digital communication and mass customisation, the entire way design is organized and products distributed will have to be rethought, taking into account the interconnectedness of the digital and the physical. Lectures and students will together have to learn new ways of thinking about design, production and distribution, new interactions with users and new skills to meet the increasingly digital online global environment. Bringing 3D printers, and related learning on the context for changing design and production through 3D printing, into the first year design studio as eMaking within an actively eLearning approach, begins the development of students who can work freely between screen and reality, digital communication and production and understand the global contexts of their work and its impact - in its broadest sense - on the world.

### 3.3 Connecting to issues

The impact of 3D printing as a transformative technology, in that it changes what is possible and how things operate, and if studied as part of an eLearning strategy, it allows the lecturer practical opportunities for project work that bring in a study of contemporary issues. Intellectual property rights in relation to 3D printing is an example, product liability is another. The impact of 3D printing – if Aldersley Williams is right – on urban planning, jobs, transport. There are a myriad of implications that arise from learning strategies that bring the online and offline together through 3D printing, with the potential to 3D print plastic guns and at the same time, replacement kidneys. Bringing this area of study into the classroom allows the lecturer to encourage the student to explore philosophical and ethical issues within project work. For example, in the project shown in figure 3, the student was interested in the use of biomaterials to create a scaffolding for a damaged heart that was 3D printed to allow the patient's own cells to grow around it. The student suggested the potential to then alter the structure of a functioning heart and worked with a pathologist and cardiologist to develop and 3D print a provocation piece for discussion on the ethics of human engineering research.

*Figure 3. Heart provocation models by MA student Kaecee Fitzgerald (a) 3D print from the CAD model; and (b) 'Double pump' heart in action showing flow*

## 4 CONCLUSION

Leonardo Da Vinci advocated that in studying science, it was important to develop a 'complete mind', and to realize that 'everything connects to everything else' [14]. Over the last ten years this became much clearer to Product Designers as sustainable design encompassed full lifecycle analysis, but meanwhile a predominantly modularized system of learning was fragmenting the design studio experience and the individual design programs were mainly taught in isolation within academia – even from peer academic institutions. Practicalities prevented the web of communication and interaction that is characteristic of real world design process as a whole being echoed in the learning experience. However, the emergence of Web 2.0 and additive manufacturing is starting to provide an opportunity for design education to be the interconnected experience that it is in the reality of good design as a practice. As the barriers between screen and reality are breaking down in the classroom, so are the barriers between the classroom and the real world, between design institutions globally, and in relation to understanding the complexities of design with respect to society, the environment and economics and the impact of this understanding of educational practice and the student's understanding of themselves as designers.

"When teachers want students to enhance their human interaction capabilities, they have to find ways to help them become more self-aware and other-aware in relation to the subjects being studied" [15]. In design education, the development of proactive, lifelong learners who understand the role of design in the operation of world affairs and the potential impact of their decisions, however small and isolated they may at face value appear, on people and place is paramount because of the cumulative effect of incremental change [16]. By embracing an eLearning strategy in its most ambitious sense, with eMaking embedded, lecturers are able to finally break Product design education out of the silos of university conventions of teaching and put it back into the centre of everything, where it necessarily must be in order to genuinely work within the complexities of a global society and meet needs of people and place for future generations.

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# TECHNOLOGY AND INTERACTION IN THE REALM OF SOCIAL DESIGN: ROLE, INFLUENCE AND VALUE

**Inês VEIGA and Rita ALMENDRA**
Faculty of Architecture, University of Lisbon

**ABSTRACT**
Social design is the most commonly used term to identify an emergent design area that applies its process, thinking, skills and tools to answer complex social problems. Its practices, methods and outputs are unconventional and probably result today in new ways of working with and using technology. However, there is no tool or way in the design community capable of recognising the actual influence, role and value of technology and interaction, partly due to a generalized lack of research in this domain. So the challenge is to gain deeper understanding on how and why technologies are being used in social design projects. Are they assets or obstacles? Do they slow or speed up processes? Are they means or solutions? How they affect and are affected by this new social context in design? In this paper we analyse several social design projects identifying 'what', 'when', 'how' and 'why' technology and interaction appear or determine these projects. Moreover, we aim to build a pre-model analysis capable of recognising the influence and value of technology in the social design realm.

*Keywords: Social Design, Technology, Interaction, Social Design Projects*

## 1 INTRODUCTION

The relationship between technology and society has long been studied. Recently, authors have been arguing that technology provides instrumentalities and potentialities for social change, because the way they are created, developed and used always involve social choices [1]. Struggles, negotiations, compromise and delegation among interested parties – inventors, designers, investors, competitors, users, agencies of government, the media, and other people, actors or entities – shape the history of how a technology will develop [2][3][4]. Whether a success or a failure, 'the result could always have been otherwise if the trade-offs had proceeded differently' thus similar technologies 'may have different histories and uses in different nations' [2][3]. This 'indeterminacy of technological change', as opposed to the 'technological determinism' that marked earlier theories [2][5], is also based on a 'social constructivist' view emphasizing 'human agency and intentionality': 'as much as people adapt their lives to the changed circumstances created by a new technology, they also adapt that technology to their lives' [2]. So instead of being determined by technology, people manipulate, adapt and use it for numerous purposes even ones that were not foreseen or desired by its producers – in our case specifically, the designers [2][5]. Thus, the prevailing idea today is that society and technology are both phases of the same essential action of reciprocal definition [6][7] and dialectic interaction [5] – in which technologies (objects) are defined by people (subjects) and people by technologies. 'Designers have always created bridges between society and technology' authors state [8]. While creating and re-designing artefacts for society, some more meaningful than others, they have been looking mainly and primarily in the opportunities offered by the technological evolution [8][9]. Although, for the same authors this remains valid in design, they argue that the 'bridge also has to be trodden in the other direction: to look at social innovation, identify promising cases, use design sensitivities, capabilities and skills to design new artefacts and to indicate new directions for technical innovation [8].' Indeed, instead of using technological advances as starting points, some designers have been successfully combining 'normal technologies' in new ways for original purposes [8]. Along the last 60 years the essence of design – solving human problems – had different materializations and ways of action on the part of designers. Eventually, they realised they could not avoid the systemic implications of their actions and that social context was crucial to the meaning and success of their solutions [10][11]. But for some designers the social context also became the primary reason to design [12], applying their design skills, processes, thinking and tools to solve more socially and human relevant problems and priorities, usually more complex than the market-oriented ones [11]. Nowadays, we call this Social Design: multiple practices in which designers are creating, working, testing and proposing new models and alternative solutions together with all stakeholders – actors and people who possess the diffused human ability to design without being experts [8][13] – able to answer real human needs and change critical situations into more desired and sustainable ones [8][10][14]. On the course of this research we noticed that little has been found about how these designers use, create and work with technology, moreover its influence, role and value in the social design realm. Therefore, we propose to look at social design projects that used and created technology and begin to understand this relation.

## 2 SOCIAL DESIGN PROJECTS

The rationale for the selection of the projects was to gather a sample that first and foremost would characterize the nature and scope of social design. So we looked into multiple social design practices and in the work of its respective practitioners and found a range of projects in which various kinds of technologies appear and play different roles. Since 'needs are the central driving force uniting technology and business' [15] we also wanted projects to address diverse societal issues, thereby dividing them into seven broad categories which represent the main problem addressed by designers, taking into account they cross several of them simultaneously: Communication, Culture, Economy, Education, Environment, Living and Mobility. Dealing with Communication are: **2 de Maio todos os dias: Na minha rua**, a wall painted map of the neighbourhood in which inhabitants can mark occurrences and describe them to the project's team, who then reports to the City Council's website **Na minha rua** since the majority of them doesn't have internet access1. **Google Health,** an online personal health record service which provides additional information about 'health conditions, medications, and lab results'. **Make it work,** a network of public sector organizations designed for them to work together and coordinate services to support unemployed people in Sunderland, England, and offer schemes suitable for their specific needs. **Project Mwana** which uses a RapidSMS system to deliver immediate infant HIV test results to mothers living in rural areas in Zambia. And **Young people's use on the Tax System,** a series of audio recordings reporting the young people's experience using the Danish Tax Authorities (SKAT) online system and services. Projects related with Culture are: **A Gente Transforma: Várzea Queimada,** a project where designers and local craftsmen combined both their technologies and shared technical knowledge to design two product collections. **Hövding,** a cycle helmet worn around the neck with a changeable shell in numerous colours that conceals an airbag system triggered by sensors which monitor the cyclist movements. In Economy are: **Prove 'Promover e vender',** a Portuguese example of the many European initiatives and projects connecting farmers directly with consumers which distributes local and organic products in a short market circuit fostering closer relationships between them via communication technologies. **We are the Million,** a crowd funding website for small businesses in London to raise funds from their loyal customers, and crowds of other 'online' supporters, so they can create new jobs or improve their services. Related with Education are: **2 de Maio todos os dias: Football Nets,** a workshop session with children to produce and personalize street football nets using the Rapid Prototyping Machines at the fab lab of the Faculty of Architecture. **Jerry the Bear,** an interactive toy for children with type-1 diabetes to learn and practice medical procedures. **One Laptop per Child,** a project to distribute laptops with educational software for schoolchildren in 'developing countries' [16]. And **Wheelchairs in Guatemala,** a one year workshop with industrial designers and technicians from a local organization specialized in producing wheelchairs for children to perform a design project: develop a wheelchair adapted for its users – children – and the context of use. Related with Environment is **Film Farming,** a project which combines membrane technology with hydrogel (a technology found in children diapers) to replace the soil on any surface and grow sustainable and high-quality vegetables and fruit. The Living category includes **Giradora,** a blue bucket with a spinning wheel that works as a washing and drying machine operated by pedals. **Kinkajou,** a microfilm projector that is able to both illuminate and support teachers' work in night time adult literacy classes in off-grip rural areas of west Africa. **Moonlight,** a students' project in Design for the Base of the Pyramid Program at the Faculty of Industrial Design Engineering, TU Delft, consisting in a portable solar-powered light for people in off-

[1] **2 de Maio todos os dias** is a project that works on multiple – social – issues in *Bairro 2 de Maio,* a disadvantaged neighbourhood with high unemployment rate in Lisbon.

grid areas of rural Cambodia. **Na minha rua,** a website where citizens of Lisbon can report street occurrences to the City Council. And **Pump Away,** a vacuum pump truck with an omni-injector to empty and maintain good performance of pit latrines in Zambia. Related with Mobility is **Boleia.net,** a Portuguese car-sharing website to connect people interested in sharing car trips and its expenses or simply to communicate with others who share similar interests (networking).

## 2.1 The Inquiry: What, How, Why, When, Who

For most people, still, technology is *material* – 'machines', 'mechanisms' or 'mechanical modes' [1]. However, as we witness in the XXI century, its physical aspects are increasingly the surface and/or interface of more crucial and complex technologies, ones that are *immaterial*, or as some authors call 'intellectual' [1][5]. 'Technology' comes from the Greek term *techne* meaning 'art, craft, skill' and *logia* meaning 'word, knowledge' and its defined as the set of tools, machines and instruments and also methods, knowledge and processes that belong to any art, craft or technique or can be used, made or modified to perform specific functions, solve particular problems or achieve determined goals [17][18][19]. So, *what* are the technologies identified in our sample: *material* (tangible things, tools, instruments) or *immaterial* (methods, knowledge, process, programming, linguistics, algorithms and other internet related tools)? *How* they occur in the projects: are they *used, created* specifically, or *extended*, in Bell's notion of 'extension technology' as providing additional scope to an existing technology? *Why*, or for what purpose they appear: to *solve* (solution) or *support* (a means to an end) the project? *When* they appear: in an initial, intermediate or final stage of the process? *Who* directly interacts with it to fulfil its role? These were the questions of our inquiry to the social design projects and in Figure 1 below we can see the answers.

| | | Technology | What | How | Why | When | Who |
|---|---|---|---|---|---|---|---|
| 1 | **2 de Maio todos os dias: Na minha Rua** Ongoing, Portugal / U:iclc | Neighbourhood Map | M | Extended | Support | —●— | U + D |
| | **Google Health** 2009-2011, Global / Google | Online Record System | I | Extended | Solve | ——● | U |
| | **Make it work** 2013, U.K. / Live \| Work | Online Network System | I | Extended | Solve | —●— | O |
| | **Project Mwana** 2010, Zambia / UNICEF | RapidSMS System | I | Used | Support | —●— | O |
| | **Young people's use on the Tax System** 2013, Denmark / Mindlab | Audio Recorder | M | Used | Solve | —●— | D |
| 2 | **A Gente Transforma: Várzea Queimada** 2012, Brazil / Rosembaum | Craftsmanship | I | Used | Support | —●— | U + D |
| | **Hövding** 2005, Sweden / Cityfabric Labs | Airbag System | M | Extended | Solve | ——● | U |
| 3 | **Prove: Promover e Vender** 2006, Portugal / EQUAL Initiative | Online Ordering | I | Used | Support | —●— | U + O |
| | **We are the million** 2013, U.K. / Participle | Online Crowdfunding | I | Extended | Solve | —●— | U |
| 4 | **2 de Maio todos os dias: Football nets** 2014, Portugal / U:iclc | Prototyping Machine | M | Used | Support | —●— | U + D |
| | **Jerry the Bear** 2009, U.S.A. / Design for America | Interactive Toy | M | Created | Solve | ——● | U |
| | **One Laptop Per Child** 2005-2009, U.S.A / MIT Lab | XO Laptop Computer | M | Extended | Solve | ——● | U |
| | **Wheelchairs** 2011-2012, Guatemala / Design without Borders | Design Process | I | Used | Solve | ●—— | D + O |
| 5 | **Film Farming** 2013, Japan / Dr Yuichi Mori - Mebiol Inc. | Membrane Technology | M | Used | Support | ●—— | D |
| 6 | **GiraDora** 2011, Peru / Master Students - Art Center College California | Washing Machine | M | Extended | Solve | ● | U |
| | **Kinkajou** 2004, Mali / Design that Matters | MicroFilm Projector | M | Extended | Solve | ——● | U |
| | **Moonlight** 2009, Cambodia / Master Students - TU Delft | Portable Lamp | M | Extended | Solve | ——● | U |
| | **Na minha rua** 2013, Portugal / Lisbon City Council | Interactive Website | I | Used | Support | —●— | U + O |
| | **Pump Away** Ongoing, Zambia / IDEO | Omni-Ingector | M | Extended | Solve | ——● | D |
| 7 | **Boleia.net** 2013, Portugal / Lindoweb | Community Web Portal | I | Used | Solve | ●—— | U |

1 COMMUNICATION 2 CULTURE 3 ECONOMY 4 EDUCATION 5 ENVIRONMENT 6 LIVING 7 MOBILITY ——— MATERIAL [M] IMMATERIAL [I] USER [U] DESIGNER [D] ORGANIZATIONS [O]

**Project references (from top):** www.2demaio.com; en.wikipedia.org/wiki/Google_Health; liveworkstudio.com/client-cases/415 + (McNabola, A. et al. 2013); www.frogdesign.com/work/portfolio?tid=106 + unicefinnovation.org/projects/project-mwana; mind-lab.dk/en/cases/away-with-the-red-tape-for-young-taxpayers + (McNabola, A. et al. 2013); www.rosenbaum.com.br/agentetransforma/edicao-2; www.hovding.com + designtoimprovelife.dk/hoevding; www.prove.com.pt; www.wearethemillion.com + www.participle.net/projects/view/279/; jerrythebear.com + designforamerica.com/projects/jerry-the-bear; (Kraemer, K.L. et al. 2009); www.norskform.no/en/Themes/Design-as-development-aid/Prosjekter-2012/Rullestolprosjektet/Wheelchair-design-/; www.mebiol.co.jp/en/aboutus + designtoimprovelife.dk/film-farming-with-hydrogel; www.designmattersatartcenter.org/proj/safeaguaperu; www.designthatmatters.org/impact/#kinkajou + http://www.youtube.com/watch?v=5B_RK61NI1Q; (Diehl, 2009) + (Kandachar, 2009); lxi.cm-lisboa.pt/lxi/?application=NaMinhaRua; www.ideo.org/projects/new-options-for-improving-pit-latrine-technology-in-zambia/completed; www.boleia.net.

*Figure 1: Technology in Social Design Projects*

# 3 THE ROLE, INFLUENCE AND VALUE OF TECHNOLOGY

As we can see in Figure 1, most of the technologies are solutions because how they appear allows the project to be accomplished, or solved. However, if we look carefully this doesn't mean that the project ends with their creation, use or extension. In fact, the solving technologies appear – *when* – alternately in initial, intermediate and final stages of the project indicating that their role depends on other actants, sometimes technologies – *material* or *immaterial* – that also play role in the process. Although the 'Interactive toy' **Jerry the Bear** is the solution of the project, many technologies helped in his creation and support its function when it interacts with and by children e.g. the software built by a specific programming knowledge allows children to interact with the toy, the touchscreen serves to activate the software functions, the audio player emits sound expressions for every function performed or activated such as 'Thank you' or 'I'm Hungry', among others. Thus, in every project technologies don't act as separate or individual elements because they need interaction to perform its functions they constitute parts of a whole, system or chain [6][3][17][4] of relations and associations of various technologies and various people, who create, use and interact with them to accomplish the goals of the projects. Consequently, delegation – the 'distribution of competences' between people and technologies [6] – plays a very important role in social design projects. It is decided not only by designers but also by technologies themselves which 'contain and produce a specific geography of responsibilities' or 'causes' [7]. If we imagine what people would have to do in place of a technology we are able to identify delegation and understand the role of the given technology within the project [4]. When women in Cerro Verde, Lima, Peru, delegated the task of washing and drying clothes to **Giradora** they were liberated and no longer needed to make several trips up and down the hills to collect water saving time for other, more rewarding, activities. By using a RapidSMS system, **Project Mwana** was able to effectively replace the postal system that took up to four weeks to deliver the same test results. By delegating to a mechanical solution **Pump Away** largely improved the efficacy and efficiency of the cleaning service of pit latrines that otherwise by hand was too hazardous, time consuming and unsustainable. These three projects happen in similar contexts where people lack basic human needs/rights, living at the 'Base of the Pyramid'. Nevertheless, the delegation present is not, in our view, a process of 'deskilling' [20] nor of 'dehumanization of work' [10] since the substitutions or replacements of people by technology are positive, healthy and the benefits are mainly human, social and cultural. City Management and its state – of cleaning, maintenance, security, etc – is a task which the Lisbon City Council cannot ensure entirely and permanently so it delegated to its citizens the role of actively and permanently detect and communicate street occurrences. The website **Na minha rua** is the bridge between the authorities who have the power and means to control occurrences and the citizens who participate and take responsibility for the city in a more open, flexible and horizontal model of governance [8]. On the other hand, the Council can improve time and resource management, prioritise urgent actions and gain greater control over the city by or through its citizens. Technology is not neutral it embodies the strategy of its 'protagonists', designers who rework or reproduce the existing time and spatial structure of historical, economic, political, technical, and sociological opportunities and constraints [3]. Consequently it is 'inherently political' exerting more or less 'social control' by, consciously or unconsciously, opening or closing certain socio-technical options, patterns or relations, impose certain rules or norms offering immediate rewards or abrupt penalties to 'groom' or 'teach' the users [17][7]. In Sweden, two designers decided to create an urban cycle helmet that people would be happy to wear, even if it was not mandatory. From an user's point of view, the choice for not wearing one has been due to several reasons: not very comfortable to wear, not that protective, resembles the ones used by professional cyclists and mainly the person's hair becomes a mess. However, **Hövding** ends with any excuse for not wearing a helmet because it has a changeable shell that can easily match people's outfit and since it's worn around the neck it doesn't mess up your hair anymore. According to authors, when adopting technology we are opting for far more – economically, politically, culturally – but it always depends on the people's choice and use of technology seeing that when they use it, respond to it, interact with it, they change it. 'So the fate' of technology or its consequences are always 'in the hands of others' [4][10]. Most of the projects *use* or *extend* – adapt, alter or provide additional scope – an existing technology, and very few *create* them specifically. In some projects, this can be due to available means or resources or even the strategy and interest of the State to invest in technological change [5]. Nevertheless this shows that the choice/design of more 'low' or 'high' technologies hinges on local circumstances particularly the need for the part to integrate a whole [8][17]. **Kinkajou** is an example which the combination of existing technology created a new technology. The 'Online ordering' website of **Prove 'Promover e vender'** is the low-cost mediator that enables farmers to reach out costumers and vice-versa. **We are the million** *extended* the crowd funding platform to a more curate, thoughtful and appealing website. Internet platforms work effectively as communication enablers and system organisers however, according to authors, they are still largely unused [8] and could reduce drastically the amount of 'hardware' [10] present in our societies proposing sustainable alternatives to current production, logistics, distribution and consumption methods [21]. Social networking services, or ‘social media’, can be present in any project simply by members of teams contacting each other and sharing information through them. They can also catalyse large numbers of people around common visions, foster peer-to-peer relations and support meetings and efforts ‘in the real world’ as **Boleia.net** [8]. In the public sector, authors state that design plays a significant role in the introduction of successful technology because it can actively and creatively increase service efficiency, reduce costs in creating, adapting, using, testing and implementing and most importantly better identify and meet real user needs [22]. **Young people’s use on the Tax System** and **Make it work** are two examples. In the list of *immaterial* technologies, some of them cope not with the direct creation or application of technology but with the transfer of technological knowledge or skills. **Jerry the Bear** is again an example in which knowledge is transferred and taught by the interaction with the technology. Design interaction is about designing actions or artefacts for intended use and/or to mediate human relations [12]. The projects **A Gente Transforma** and **Wheelchairs in Guatemala** introduce a recent take on design and its knowledge as an enabler for people to re-think, change and improve their own lives and designers as ‘people with design knowledge’ who aside from designing artefacts can also design interactions and participations [23]. In the first example, designers and local craftsmen were involved in a mutual learning process in which both craftsmanship and design knowledge interacted to create two original and distinct product collections. The designers of **Wheelchairs in Guatemala** though the best way to assure wheelchair technicians would effectively improve their expertise was to perform a design project, from beginning to end. According to authors, ‘as individuals work together they are able to build a rapport that facilitates knowledge transfer’ and when they ‘already share a common language within a domain additional knowledge can be more easily transferred’ [21]. In this case the technology – the design knowledge – was the prior solution but only when interaction with it occurred the project's process could develop. Indeed, **Wheelchairs for Guatemala** was not a project about designing technology – the wheelchair for children – but designing interaction – the collaborative process of the design project – with the purpose of technology – knowledge – transfer and learning. During the workshop **2 de Maio todos os dias: Football nets** the children learned how to work with the machines and that was the most exciting part of the workshop as they stated. The fundamental aim of the activity was for them to eventually use the machines in the future, in their free time, for their own projects and needs. For some authors, the transfer of innovative technology – *material* or *immaterial* – has to be ‘sensitive to social, cultural and economic differences’, based on local priorities, levels of interest, feasibility and ‘appropriateness for the community’ in terms of infrastructure, environment, waste management [8] and existing human relations and social dynamics since people are often a crucial part of ‘what is worked with and changed’ [24]. **One laptop per child**, was an example that failed to comprehend the social, cultural and economical context. The XO laptop was seen by its designers as a transformative technology that would change education ‘for the world's disadvantage schoolchildren’ [16]. Their ambitions were set up high but in our view for the problem they were trying to tackle the XO laptop could never be the solution. In the best case, it would have been a supporting technology because it needed the interaction and involvement of teacher's who were the main characters introducing the technology into classrooms and transferring the knowledge to children. However, they were never involved, nor even trained to work with the laptops [16]. Moreover, the project ‘had no one handling marketing, deployment and support’ so the cost of the computers ended up being too high for children, and their parents, despite the government's investment [16]. Learning from mistakes and failures, this project whistles the importance of the participation and integration of users, people for whom the solutions are intended, and all stakeholders in the process of designing, implementing, distributing and communicating technology [20]. Especially in large-scale projects, it is important to test and prototype solutions directly with users since the dialectic and iterative approach can assess and anticipate empirical, political, material and symbolic issues simultaneously [20]. Thus, authors state that the designers' ability ‘to engage with users, discover their needs and create solutions accordingly is what makes technology into something people can use’. **Moonlight** was considered a successful project that from a design education point of view was more than ‘designing a product’ it was a process of successfully introducing technology in a specific context and the development of a locally adapted solution through ‘Transdisciplinar approach’, ‘participatory methods’ and ‘different design knowledge domains like sustainability, user context and business’ [25]. For this reasons, authors argue that ‘design professionals and educators should invest more in research and education for Designing for the

BoP' [25]. Indeed, these programs present great opportunities for students to gain hands-on experience in designing – products, technologies or services – for social contexts and are thus potential protected micro spaces of experimentation of social and technological innovation [8]. The **Google Health** project was discontinued for not having the expected broad impact. In our view, the project posed questions of privacy and usefulness for all users – whether doctors and people. Since the data was added voluntarily it was propitious to errors, misunderstandings and incompleteness. Also the centralization and disclosure of information to an online platform as its advantages but also its risks.

### 2.1 Final considerations

Authors say that technology – or the lack of it – reflects the ability of societies to transform themselves and the uses to which they dedicate their technological potential [5]. Social design projects *use*, *create* and *extend* technology both as means and solutions to human centred problems in various domains of society. Some more complex than others, all of them reflect the principles guiding the work of social designers who instead of designing just another – original, more beautiful, different – lamp, they design sustainable lamps or devices which illuminate and perform other functions simultaneously for where there's no light. Instead of another helmet they think about meaning, relevance, value, ethical intentions and the political strength of *things* – technologies – they create/design. Instead of adding, they question, propose alternatives, and try to change situations, even when they fail. So, although all design is social, not all design is social design. From our analysis technology plays a positive role in social design. Our framework enabled us to recognise its nature, materialization, purpose, timing and operation in each project. However we cannot be certain if this can work as a pre-model analysis for technology in the social design realm. Overall, technology facilitated processes, mediated relations, connected people, enabled communication, organized systems or networks and were delegated to specific functions that otherwise would take much longer to perform or implicate more resources to be done. As knowledge it was transferred, improved abilities, helped and empowered people. Some technologies have potentials that are yet to be explored, especially the ones related with information, communication and networks. Technology itself is not an obstacle but the way it is introduced can lead to its rejection. Therefore, we can say that technology is useful, both technically and socially, for social design projects but we are only in the beginning and much has still to be done.

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# WHERE'S MY ROBOT? INTEGRATING HUMAN TECHNOLOGY RELATIONS IN THE DESIGN CURRICULUM

**Wouter EGGINK**
Industrial Design Engineering, Faculty of Engineering Technology, University of Twente

**ABSTRACT**
In today's society, and in almost every forecast for the future, technology development plays a major role. From theories in Science & Technology Studies we learn that the development of new technology cannot be meaningful unless there are users that successfully adapt the products and services to their own lives. As a result, it is important that designers learn to explore the interrelationships between engineering and behavioural, cultural and social issues. Within our Industrial Design Engineering curriculum we therefore emphasise the influence of technology on human behaviour and vice-versa. Although every specific product and context demands for a specific relation, we have experienced that there is common ground in the developments of these relationships that makes our education work. At a higher level of abstraction, the human side of the relation stays merely the same, because human bodies and human needs and emotions do not develop fast. It is only the technology side of the relation that develops and therefore changes the relationship. Thus, by starting from the human side of the relationship, the technology side can be consciously developed and shaped. A carefully designed series of courses in Design Aesthetics, Philosophy of Technology, Cognitive Ergonomics and Usability develops the students ability to analyse the human needs and characteristics, to understand the impact of technology, and provides the skills to shape the desired relationships. And although we do not design robots, our experience with Industrial Design Engineering is that human technology relations are apparent within all sorts of design challenges.

*Keywords: Human-Technology Relations, Design Curriculum, Curriculum Development, Technological Mediation*

## 1 INTRODUCTION

In today's society, and in almost every forecast for the future, technology development plays a major role. For industrial design, the incorporation of smart products, like robot nurses, robot pets or even robot personal trainers, is often referenced as a solution for an ageing society where healthcare costs are going through the roof. On the other hand, at present the only robot type with considerable market penetration is the simple vacuum cleaner. So are these robots preferable solutions with respect to the users, bearing psychological and social needs of people in mind? To answer this question, one must learn to have a close look at the relationship between the user and the robot.

*Figure 1. Human-Product relations in healthcare; the traditional device evokes undesirable associations, but is the robot a preferable solution?*

Figure 1 illustrates some of the problems with a particular user-technology relation in healthcare. The device on the left evokes undesirable associations, which can be either suppressed when the device is controlled by direct manipulation of the patient by a caretaker or even strengthened when for instance the nurse stands at some distances and steers the device with a remote control. The feeling of being a 'thing' will be very strong with the patient in the latter occasion. The friendly appearance of the robot device on the right will probably overcome this, but the feeling of unease can remain because the robot cannot stand the comparison with a real nurse [1]. A comparison that is induced exactly by the friendly humanoid layout of the robot.

To prepare our students for the difficult task of dealing with these sort of issues regarding the development of the products of tomorrow, we developed our curriculum towards an integrated view on human-technology relations. This paper will describe the theoretical framework and educational principles underlying this integrated view, highlight some aspects of the related courses, and show some typical results from student's at several stages of the Bachelor and Master.

## 2 THEORIES OF HUMAN-TECHNOLOGY RELATIONS

From theories in Science & Technology Studies we learn that the development of new technology cannot be meaningful unless there are users that successfully adapt the products and services to their own lives [2]. To illustrate this concept we look at the example of the Videophone. As early as in the 1970s, this technology was available, but never came through to gain any considerable market share. Of course there was the difficulty of having the first Videophone in town and not being able to video-call anyone else. But the telephone faced the same problem when it was introduced and became a large success because there was a need for communication among the people (especially under bored housewives of the American country-side). Apparently there was not a need to actually see your friends while calling them in the seventies, eighties or even nineties of the 20th century. However, in the end video-calling became widespread when it was transformed to the cheap (for free) online service of Skype and FaceTime. Of course the financial threshold was eliminated in this way, but by the increase of travelling, working abroad and studying all over the world, also a human need for video-calling emerged. When it is no longer possible to simply call people for a face-to-face appointment because they are too far away, the video system fulfils a real need for actually 'seeing' your friends and relatives.

So the success of technological development does not rely on the level of sophistication of the engineering alone, even it is not determined by the level of usability or the pleasure and emotion gained by using the artefact. In fact, also developments on a social and societal level play a major role. As a result, it is important that designers learn to explore the interrelationships between engineering & technology, as well as behavioural, societal, cultural & ethical issues [3]. Within our Industrial Design Engineering curriculum we therefore emphasise the influence of technology on human behaviour and vice-versa. With a carefully designed series of courses throughout the Bachelor and Master, we prepare our students to shape the future of technology in a way that is meaningful to the individual user, meaningful to social groups and networks, and also meaningful to society at large.

The theoretical framework behind the courses is adapted from a combination of Science & Technology Studies, design aesthetics, behavioural sciences and usability [4]. Especially the theory of Technological Mediation [5] is used to explain, analyse, explore and eventually consciously design, human technology relations.

## 3 IMPLEMENTATION IN THE CURRICULUM

In our Project Based Learning environment [6], we work with three distinctive learning lines to cover the discipline: Engineering, Humanities, and Designing. To achieve the desired level of proficiency with these topics, each learning line comprises of three stages. We discern a basic course, normally positioned in the first year of the bachelor curriculum, a phase aimed at broadening the perspective and a phase aimed at gaining more in-depth knowledge [7]. Within this matrix of learning lines and learning phases, several courses in Design Aesthetics, Philosophy of Technology, Cognitive Ergonomics and Usability address the topic of human technology interactions from different perspectives. Table 1 gives an overview of the distribution of courses that specifically address human-technology relations across the several phases. The essential stage of integrating the knowledge is done in individual- and group design projects throughout the entire curriculum.

*Table 1. Courses that address human-technology relations and the learning lines*

| | Basic Course | Broadening the perspective | Deepening the subject | Master phase |
|---|---|---|---|---|
| **Designing** | Methods of Form[1] | Human-Product Relations[2] | Design & Meaning | Design & Emotion, Create the Future |
| **Humanities** | Physical Ergonomics | Human Product Relations[2], Cognitive Ergonomics | Philosophy of Technology | Scenario Based Product Design |
| **Engineering** | Smart products | Design of Interactive products | - | Sources of Innovation |
| [1]) See also [8]<br>[2]) This course is an integrated course from both Designing and Humanities | | | | |

## 4 EXAMPLES

In the second year of the Bachelor curriculum we start the integration of approaches on human-technology relations in a course called human-product relations [4], where the students have to design a piece of street furniture. The technology-component at this stage is not very complex, but this subject is very suitable to explain the concepts of mediating technology and behaviour change. In the example of Figure 2 for instance, it is clear that the seating suite on the left induces people to sit straight, at pre-defined distances from each other. The seating suite on the right leaves more room for interpretation and allows people to sit very close to each other or not, and at either side of the table. The picture shows also that the use of products is not always the same as intended by the designer.

*Figure 2. Examples of street furniture to explain the mediating effect of technology*

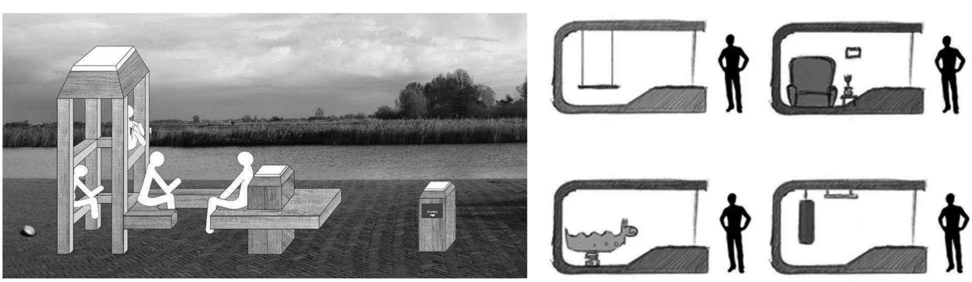

*Figure 3. Street furniture concepts by Jessica Schraa (left) and Hieu Nguyen (right), 2011*

Figure 3 shows two student results of the course. The ‘Loswal’ concept by Jessica Schraa is a hangout for tourists in a typical Dutch Canal-side environment. The concept does allow for different arrangements of people like the garden table in figure 2. It caters for sitting alone or together and also

in a high or a low position for different views on the landscape. The concept also mimics typical harbour equipment. The bus shelter concepts by Hieu Nguyen work in a slightly different way. They do not so much emphasize the physical relationship with the street furniture but rather a psychological one. The passengers that have to wait in the bus shelter are invited to spend their time playing around with the objects that are added to the simple shelter. The somewhat unusual objects therewith also have a second function as conversation starter between strangers.
The second example, comes from the master course Create the Future. Although industrial design is always future oriented by nature, in this course students have to develop an innovative product for in at least 25 years' time, and have to design the future context for their product themselves with the aid of scenario development [9]. The technology involved here is more advanced, especially because the students can make use of the expected developments in future technology, based on Delphi Studies. The design concept that is shown here is made for Philips healthcare. To quote the students themselves: "future studies allow companies to explore and pursue future opportunities. Therefore it is an important skill for designers to be able to develop and work with a long term vision." [10] p.7].

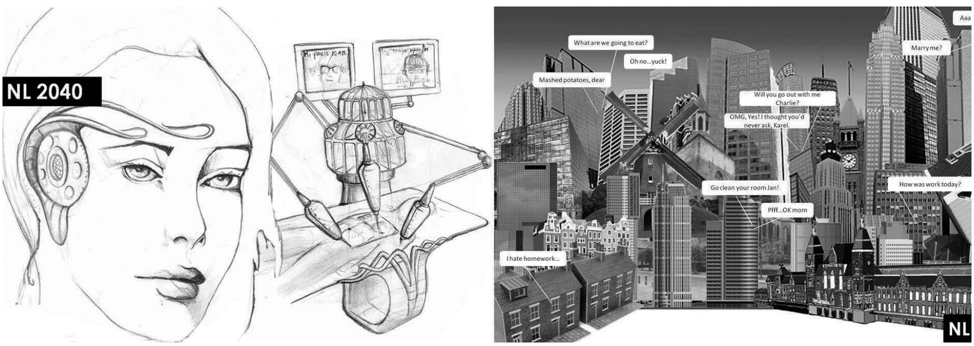


*Figure 4. Scenario visualization "Healthcare in the Netherlands in 2040" by Ida Nordlöf, Liesbeth Stam and Ani Hovhannisjan (2012)*

Figure 4 shows a visual of the scenario context that was developed by the group. They explain: "We believe that the most realistic future is characterized by free markets and an overall positive attitude towards technology. People in 2040 believe that technology rather enhances their lives than harms it. In 2040 health has become a commodity for both sick and healthy people. Everyone is responsible for their own health. It is not only technologically possible for people to design their lives into the smallest detail, but they also have the freedom to do so. Endless possibility and full responsibility for one's own success in life can make life-management rather stressful." [10] p.3].


*Figure 5. "Emotivator" concept and storyboard by Nordlöf, Stam and Hovhannisjan (2012)*

Figure 5 shows the developed product concept of the "Emotivator", and a storyboard explaining the human-product relation: "In this demanding future we have developed a product concept that we named Emotivator. The Emotivator is a life-management assistant that will motivate the user to pursue his/her goals. Emotivator aims to stimulate individual flourishing and diminish stress in the demanding, but colourful society in 2040 in the Netherlands." [10] p.3]. And although the technology acts as a personal agent that helps people to achieve personal goals, like relaxing better (Figure 5) or eating healthier or doing more exercises, it does not mimic the shape of a real personal assistant, but is rather concentrated in a jewellery like object. This association with jewellery is not random; it was argued that the achievement of personal goals were indeed a very personal issue for the user, that needed for an object with which an intimate and 'valuable' relationship was possible.

## 5 COMMON GROUND

The two examples that are presented here are very different, and also our experience with ten years of developing the education of human-technology relations is very broad and diverse. So at first sight every human-product relation is characterised by the specific context of the user, the associated user groups, the product and technology type, and the social and societal context. Looking at a higher level of abstraction however, there is a common ground in the development of these human-technology relations, which make it work; although the characteristics of the technology side of the relation are always changing due to development of new technological possibilities, at the human side however, the characteristics stay largely the same over time. We come to know more and more about the workings of our human bodies, but the bodies itself scarcely change. So we have a lot more data on the measurements of the human body since the description of the Vitruvian man by Leonardo Da Vinci, however the contemporary remote control can have just the same shape as an axe from the Neolithic because it suits the same human need: to fit in the hand (Figure 6).

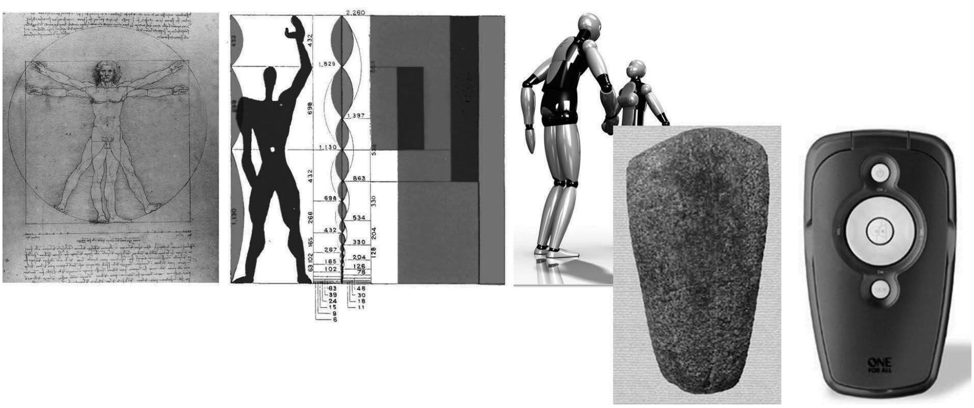

*Figure 6. The Vitruvian man (ca.1490), the Modulor (1948) and a contemporary 3d Human Model (Dined). Below a fist-axe from the Neolithic and a contemporary remote control.*

This effect is again visible on the three previously mentioned levels: the individual, the social and the societal. On a social level, one can think of the use of Facebook to inform friends about the things that you experience and like. This serves an underlying human need to share your thoughts with the ones that you care about. Before the development of the internet this was done by writing letters. Not so convenient and certainly not that immediate, but the principle is the same. There is also not much difference in going to a Shakespeare play in the 17th century or watching a StarWars movie in the cinema. In both situations one is entertained with a story about good and evil. And the introduction of 3d movies lately does not change the need for entertainment, it just alters the way we 'experience the experience'. It is also no wonder that we still go the cinema with friends, despite all the development in television screens at home and the competition in entertainment from the internet. It is the underlying desire of people to have a shared experience, an experience where one can talk about and share memories afterwards.

In the education of human-technology relations, this means that we have to start from the human side of the relation. Investigating, exploring and characterizing the human needs on all levels of the occasion. From there on, the technology can be modelled and adapted to suit the occasion. Of course the technology does not necessarily have to slavishly obedience the human needs, but can also be designed to influence the human behaviour for better health, a better society, better sustainability or whatever higher goal is desired. A proper insight in the needs and cravings of the humans involved remains however indispensable to make the human-technology relation a viable one in the end.
When we look at the user-technology relationship of figure one again from this perspective, we can conclude about the desired appearance for the robot. The robot is not substituting for the need of the patient to have a social relationship with the caretaker (talking, being taken care of, feeling looked after), but is rather substituting for the strength and power of the caretaker to lift the patient out of bed (to prevent back-injuries of the caretaker). Therefore the device should not look humanoid, but rather like an industrial robot arm with a friendly finish. Preferably operated by the caretaker. When we think of more of these examples it seems logical that there are still not many (humanoid) visible robots in our daily surroundings; they do just not fit properly to our user needs and expectations.

## 6 CONCLUSION

In the end, our experience is that human technology relations within Industrial Design Engineering, is mostly *not* about robots, but rather apparent within all sorts of design challenges. The relative stability of the human side of the relationship allows for conscious shaping of the future human-technology relationship in design projects. In our cases, covering from simple street furniture to advanced personal health monitoring systems.

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# INTRODUCTION OF ISSUES REGARDING PEOPLE WITH SPECIAL NEEDS TO DESIGN EDUCATION

**Pavlina Georgieva ZABUNOVA and Yordanka TSVETANOVA**
Forest University Sofia, Bulgaria

**ABSTRACT**
The aim of this paper is to present the urgent need for timely introduction to design education the problems of people with special needs, and the claim of relevant, appropriate design solutions for them.
The report will show: who are the people with special needs, what is the importance of inclusive design in contemporary urban environment, what are the most common barriers, and conflict situations that people with special needs meet, good practices for creating environment for people with special needs, examples of introducing the problems of disabled people and establishing tolerant attitude from early age, sample projects and tasks acquainting students with the problems of people with special needs proposed by the authors.

*Keywords: Design, design education, people with special needs, people with disabilities, inclusive design, urban facilities, urban design*

## 1 INTRODUCTION

Design and application of new technologies create comfort and wellbeing in today's world. They make inventions and innovations available for a large amount of people, improve the function of objects and facilitate greatly their use. They increase the standard of people's lifestyle.
Despite the rapid development of technology and society, there are people whose specific needs do not let them lead life of full value and dwell independently in the environment.
Innovative technologies and designs are those that could significantly increase the standard of living. All the innovations and solutions are in the hands of the young architects, product and engineering designers, as well as the students in engineering specialties.
That is way the authors believe that the training of junior academics about inclusive design would solve the problems of the contemporary environment.

## 2 FORMULATION OF THE PROBLEM

### 2.1 Who are the people with special needs

People with special needs are mostly children, mothers with children, elderly people, people with temporary or permanent physical disabilities (by definition permanent physical disabilities the authors consider all people with any impairment in the sensory system, musculoskeletal system as well as blind, deaf, disabled or handicapped people and others). Society must provide specific care for them. They should not remain isolated from the environment in which we live, nor have a lower standard of living than the others. Environment and objects need to be designed in such a way that they can be comfortably used and accessible for everyone.
Technology and design in planning of environments for people with special needs can refer to any time of the daily life. Actions which healthy people perform almost unconsciously, for those with special needs require much more effort, and the participation of caring person.

### 2.2 Need for designing an accessible environment for all

By the beginning of 2014 according to the statistics 686 812 Bulgarians are with permanent physical disabilities in Bulgaria. This represents almost 11 % of the total population in the country. Throughout the European Union, the records show that around 15-16 % of the population have some kind of

disability. That amounts almost 80 million Europeans that are still discriminated and physically restricted. [1]
Society as a whole begins to understand that it has to adapt to their needs, not vice-versa. People with disabilities should be able to lead satisfactory life and decide freely for themselves. The network offers great potential to improve the social integration for people with disabilities (online operation, e-democracy, access to knowledge and information). However, particular attention should be paid to the issue of accessibility. Serious problem for labour and social equality for people with disabilities represents the accessibility to the surrounding environment. According to the National Institute of Statistics in Bulgaria by 2005 only 5 % of the disabled people admit their surrounding environment as easily accessible, 46% have encountered some difficulties, and 24% identify it as inaccessible (there is not applied information for the rest 25%) [2].
In Bulgaria there is a regulatory act since 2003 for accessibility of buildings, transport, and facilities. More than 10 years after it has been inured, there is still no significant adaptive projects for people with special needs. The greater part of the improved urban spaces and facilities after 2003 has serious gaps in the requirements for disabled people. On the other hand in the process of designing the needs and necessities of these people are considered too late.

*Figure 1. Images of a few examples of non-compliance with regulations. Photo 1. Lack of elevator or platform at the exit of the newly built subway station Sofia University "St. Kl. Ohridski "by the side of the King's Garden; Photo 2. Lack of tactile ground and insufficient space for crossing on Blvd. "Vitosha"; Photo 3. Crosswalk ending with high curb at one of the entrances of the church “St. Al. Nevsky"*

### 2.3 Most common barriers and conflict situations for people with specific disabilities

The emphasis here is on the most common obstacles for people with permanent or temporary physical disabilities. The information is consistent with the Access and Facilities for Disabled People Issued by Wolverhampton City Council in 2009 [3].

1. Difficulties that people in wheelchair face: high curbs, stairs, loose gravel and cobblestone pavements, narrow doors and hallways, not enough space to manoeuvre, lack of sanitary facilities, etc.
2. Difficulties that blind and visually impaired people face: lack of signage, confusing layouts, steps with insufficient width or have no contrast to highlight risers and treads, lack of tactile surface, obstacles, and hazards along the way, such as furniture, billboards, cars parked on the sidewalks, road works, etc.
3. Difficulties that hearing impaired people and deaf people face: noisy environments, poor acoustics and lighting environments, lack of visual information.
4. Difficulties that people with ambulatory disabilities face: lack of handrails, ramps or stairs, steep slopes, long distances and no resting places, lack of rest areas, lack of seating places, difficult to use door handles.

The design and organization of the urban and interior environment are those who can offer a solution to the mentioned problems.
From everything that is observed directly, the authors believe that the boost in solving these kind of problems comes from young designers who after graduation will be factored into practice and engaged in this cause. Design students need an extensive examination of the various types of disabilities and difficulties that these people face. Thus future designers would be more responsible while designing, in order to meet the relevant requirements for the people with special needs.
Today, the capital city of Bulgaria, Sofia, which is among the oldest European capitals, still has to solve many problems regarding the disabled people. Although the alert in various media and

institutions has started paying attention in that direction, there are still many things to correct that consider the design of private and urban environment.
There is a study course "Design environment for people with disabilities" with a minimum 45 hours of workload in the University of Forestry. During the course students are working on three assignments. Every assignment takes five weeks and the students work individually. The first task is to design a kitchen, living room, or dining room interior where a person in a wheelchair will reside. The second one is to create a community space as a library, bus station etc. appropriate for disabled people. The final task is furnishing a home for adults where the students have to design the common room and bedroom for 1 to 4 people.
Unfortunately this useful information is available only for students studying Master degree course majoring "Living Environment" which is about 5 to 10 students a year. The rest of the Engineering Design students /numbering about 250, are not given any projects related to the needs of disabled people. Such is the case with the authors of this paper. In order to learn independently the problems of the inclusive design, the authors present their 3 projects that are personal idea and offer an adaptation of the assignments to the disabled people needs. Other majors as "Product Design" and "Urban design", despite the direct relationship with people with disabilities are not tutored in this discipline.
The proposal of the authors is that the discipline should be taught to all young designers and included in the curriculum at the beginning of the bachelor course in every design or architectural university. It is possible to extend the knowledge through additional annexes in disciplines such as ergonomics, graphic design, furniture construction, etc. Students could learn the basic ergonomic requirements for the disabled people, or where they could use Braille, how to create a clear and understandable signs for deaf people etc. In the course furniture construction for example students can construct specific furniture, to learn and explore different mechanisms for full opening of doors for easy passing, various sliding and automatic doors, ramps, mechanisms for hospital beds and others.

### 2.4 Best practices for creating a supportive environment for people with disabilities using the means of design

In some states in the U.S. in government primary schools, along with the alphabet, addition, and subtraction, the kids study sign language as well. They learn how to introduce themselves to a deaf person, how to greet and how to assist when needed. This creates a culture of tolerance and understanding from quite an early age.


*Figure 2. A card for learning the alphabet. [4]*
*The sound "A" is transmitted through the drawing of an apple and the sound "A" is marked in three ways - letter, braille letter and sign language. Apple is presented by the Scratch & Sniff as well, that way the new information is embraced through all the senses. The kids are unconsciously taught that things should be done for everybody.*

In 2006 the Council of Europe and Committee of Ministers accepted Disability Action Plan. [5] The fundamental principles and strategic goals according to action line number 6 are to create "An accessible, barrier-free built environment encourages equal opportunities, independent living, active involvement in the community and access to employment. By applying the principles of Universal Design an environment that is accessible to people with disabilities can be established and the creation of new barriers can be avoided."
Another positive example is German capital Berlin. Since 1990 people in the city have been working to improve the accessibility in the city. In the past 2013 Berlin received the Access City Award [6]. One of the greatest achievements was the supplement of the entire bus network with wide opening

doors and platforms for a better access. The goal is by 2020 to have equal accessibility in the metro and trams.

## 3 SAMPLE PROJECTS AND TASKS ACQUAINTING STUDENTS WITH THE PROBLEMS OF PEOPLE WITH SPECIAL NEEDS PROPOSED BY THE AUTHORS

In the fourth year of the undergraduate curriculum, design students should be given several projects and tasks related to people with some kind of disability. The authors suggest that students should be acquainted with the needs of these people through several tasks included in the subjects studied in the general curriculum. The projects could be done individually or in groups, the implementation period should not be less than ten training hours in order to enable students to find solutions about the particular problem.

For instance, in the course “Furniture Constructing” students can go in for construction of beds, chairs, cabinets with specific purpose or mechanisms for full opening doors for easy access, ramp, and sliding door devices. In “Residential Interior Design” classes students could design an interior space that will be used by a person with disability. “Public Furniture Design” could include designing of one or more public facilities as bus or subway station, kindergarten, school, library or administrative building with all the necessary equipment for disabled users. Thus students will become familiar with the regulations and ergonomic requirements. The authors have tried to organize in three versions their own sample projects. The first one is urban facilities design, the second and the third ones are resumption of pedestrian zone and cultural area. In these three proposals the initial tasks were adapted to the greatest extend to the topic of design for people with disabilities.

1. Development of the project for urban facilities design got transformed into "Playground for Art Therapy." In the process of creation the student meets different types of art therapies, gets familiar to the fundamental requirements for facilities for disabled and healthy children design and safety regulations. Consultation with experts is required, where necessary.
   The playground has two facilities: musical whirligig and water pump.
   Musical whirligig for children without disabilities and children in wheelchairs. In the base of the whirligig there is an installed hurdy-gurdy. The rolling plays preliminary chosen music melody. Rotation helps to strengthen the vestibular system, and the music acts as a therapeutic tool.
   The second part of the playground is water pump with wooden channels in which the water drains (designed by the company Richter Spielgeräte GmbH). Next to the channels there is a pool with clay. By using clay and water children can create different forms themselves. This therapy develops children’s haptic sensation. It is believed that in most cases the water has relaxing features. In some cases of mental disabilities if modelling with hands incite interest in the child, it might be a sign of future development.

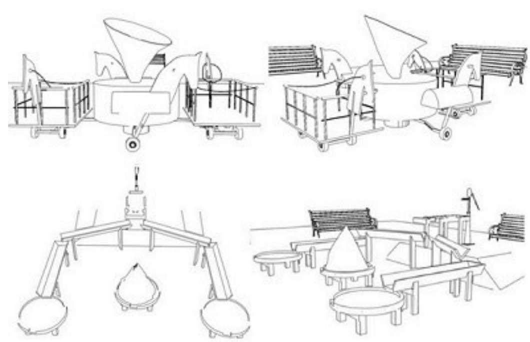

*Figure 3. Proposed design elements for the playground*

2. The second project is reconstruction of central pedestrian area in Sofia, Bulgaria. The topic of the thesis is "Rest and Relaxation Accessible for All". The area is situated at the very centre of the city and Perlovska River flows right through it. The name of the site is “Evlogi and Hristo Georgievi” Boulevard. The main aim of the project is to create an environment with more verdure and green areas suitable for recreation, walking, and relaxation by all citizens: pedestrians, cyclists, mothers with strollers, elderly people, blind and deaf people, wheelchair users and others. The place has a special significance for the city. It is surrounded by gardens and parks, has a rich history, and is situated next to a busy road. In the project the author provides paths with appropriate grounding for easy passing for everybody. Benches equipped with wheelchair spaces for relaxation are placed at a suitable distance. The information boards for public transport and the boards with historical information include text, audio, and braille. At the junction all the curbs are oblique for free passing. The tactile paving and the sound traffic lights direct blind and deaf people. There are two bus stops in the area and the student designs boarding ramps for wheelchair users, strollers, or elderly people. In the project the area is supplied with pergolas with greenery creating a visual border with one of the busiest streets in the city and establishing a feeling of natural comfort. Function of the river which now has the appearance of a channel is renewed with the arrangement of large river stones and rockeries on both shores in a natural way. The green meadows along the riverside may be used for exhibition spaces of contemporary artists.
3. The third project is called "Culture and Information for All" and its main purpose is to recover an area that is located in the administrative centre of the capital of Bulgaria. Here many sites of national cultural and historical significance are included, such as the Basilica "St. Sofia ", Temple Monument" St. Alexander Nevsky ", National Assembly Building, the building of the Bulgarian Academy of Sciences, the National Academy of Arts, National Printing House (currently functioning as the National Gallery for Foreign Art), the Central Military Club etc. The area covers green sections, two gardens, and various other elements of urban design as well. All of these objects are declared monuments and sites of tourist routes.

*Figure 4. Borders of the developed area and part of the included objects*

*Figure 5. Examples of facilities that the authors consider as appropriate samples in designing the project "Culture and Information for All" and "Rest and Relaxation Accessible for All" still in progress. Photo 1. The city of Sidney prototypes of street signs providing information to blind people; Photo 2. Braille map that emits a little beeping noise in Tokyo Metropolis, Japan. The raised yellow marking exist all over the city and guide the blind to safe crossings all over the busy streets; Picture 3 Garden furniture for commercial and public use; Picture 4 Ramp for special needs accessibility in a raised bus station in Curitiba Brazil*

Along with general requirements in the area, there are specific problems related to the usage by people with disabilities. Therefore the project provides in the zone facilities and furniture with the following elements of urban design:
Ramp with the required size, gradient, handles and flooring for the garden in front of the Church “St. Sofia” and the Cathedral “St. Al. Nevski”,

- Green pavilion (with space for wheelchairs or baby stroller) combined with bike racks,

- Green benches with space for stroller stand-alone and same benches in combination with ergonomic rotary tables for both healthy people and people with disabilities,
- Renewed information board outside the church "St. Sofia" with two text fields a normal printed and in Braille,
- Information column display and Braille keyboard showing and telling the story of Sofia and cemetery discovered beneath,
- Information stand with display and Braille keyboard will tell stories about the city history and the cemeteries discovered beneath the Cathedral,
- Audio – visual art installation “Invisible Presence” will show the people what lies beneath their feet. The installation represents a combination of holograms arranged in conical space, creating the illusion of depth and framing the boundaries of the necropolis. For blind people the information is recreated by auditory perception delivered with artistic narrative.

## 3 CONCLUSION

In conclusion the authors consider that the problem with the environmental and product design for people with disabilities or special needs is relatively new. Nevertheless, it should become a subject of study by all design and architectural fields, not only within the borders of Bulgaria, but all over the world. After all, the care for the weak and vulnerable is the character that defines us as society.

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[6] More information about the Access City Award on the website of the European Commission: http://www.accesscityaward.eu/registration/initialize.xhtm?lang=en.

# RAISING DESIGNERS' AWARENESS OF USER EXPERIENCE BY MOBILE EYE TRACKING RECORDS

**Moritz MUSSGNUG, Quentin LOHMEYER and Mirko MEBOLDT**
ETH Zurich, Switzerland

**ABSTRACT**
Understanding the interaction between a user and a product in different areas of application provides an excellent basis for the development of innovative user-oriented products. User-product-interactions usually are characterized by a combination of well-observable user actions and cognitive processes, which are considerably more difficult to detect. One method to support the investigation of user experiences is mobile eye tracking. In contrast to conventional observation, mobile eye tracking provides benefits that allow revealing previously hidden aspects of user experiences, such as the visual attention paid by the user to the product, which might lead to improved designs. This paper presents an educational approach using mobile eye tracking recordings to raise design students' awareness of user experience in an early stage. Applying the example of three different scene videos showing the interaction of a user and a power tool, an electrical bicycle and a medical device, it is described how design students can learn to analyze eye tracking data in order to evaluate aspects of usability and to identify explicit as well as implicit user needs. The paper finally discusses the appropriateness of mobile eye tracking recordings as a teaching medium to enhance the awareness of user experiences and gives recommendation for implementing this approach in design education.

*Keywords: Mobile eye tracking, user experience, user-centred design, case-based learning*

## 1 INTRODUCTION

User experience (UX) is a central element of design. Understanding a person's perceptions and responses while interacting with a product provides the great opportunity to design products tightly focused on the user's values and needs. However, user experience is known to be dynamic, context-dependent, and subjective [1]. Thus, user experience is difficult to generalize, almost impossible to explain by textbooks and consequently, challenging to teach in design lectures. Based on this insight the following question arises: How can we successfully educate design students to become aware of the high relevance of user experiences for designing a product?

One possible approach is case-based learning [2]. By meeting the user or by watching and discussing videos, which show users interacting with a product from an outside perspective, students can train to observe usability aspects and user responses. The disadvantage of this approach is that students will always be external observers and consequently, can only understand aspects of the user experiences. This is where eye tracking becomes interesting. An area, where eye tracking is already applied successfully is, for example, web design. Researchers in this area utilize eye tracking to analyze the experience of users interacting with a homepage [3]. The basis for the suitability of eye tracking to investigate in user experiences is the eye-mind hypothesis, which states that the direction of the gaze is typically associated with what people pay attention to [4]. In addition to that, eye tracking technologies provide two important benefits: (1) the user-product-interaction is recorded out of the first person perspective and (2) the user's gaze point is calculated and visualized, directly. Latter allows revealing previously hidden aspects of user experiences, such as visual attention, that might lead to improved designs. The basic idea of this paper is to combine the benefits of case-based learning and eye tracking to improve teaching user experience in design education.

The paper proceeds as follows. First, the fundamentals on user experience and mobile eye tracking records are introduced. Subsequently, three cases of the application of mobile eye tracking in case based learning concepts are described and the benefits of eye tracking are pointed out. Finally this paper presents an educational approach that uses mobile eye tracking recordings to early raise design students' awareness of user experience.

## 2 USER EXPERIENCE AND EYE TRACKING

User Experience can be understood as interplay of the four following elements: user, artefact, context and interaction [1]. In the field of product design the artefact, which is the central object of the interaction with the user, is the product to be developed, validated or benchmarked. In design education several approaches supporting user experience are already well-establish (e.g. the persona technique [5]). In this context eye tracking can even further support raising design students' awareness of user experience. Eye tracking is exercised in multiple disciples, whereas neuroscience, psychology, industrial engineering, marketing and computer science are only some examples of application [6]. The prevailing technology in use is video-based eye tracking [7]. In contrast to web design, which gets by with a stationary eye tracking system, analyzing user experience in product design requires the application of mobile eye tracking that can operate in the real environment. As illustrated in Figure 1, the mobile eye tracking system, which is used in the cases for this paper, integrates the cameras in glasses (SMI binocular glasses, 50 Hz). Besides the cameras recording the user's eyes in order to track the eye movements to calculate the gaze direction, a scene camera is built in, which records the field of vision of the user. To operate the glasses a recording unit is required, which can be fixed at the test person's belt (Figure 1, right). The output of an eye tracking recording is a dataset of gaze directions on a synchronized scene video. On this basis of these technical properties of mobile eye tracking provides four reasons, why it is well suitable to understand user experience.

- Investigations in user experience need to be done in the real environment of the application. Mobile eye tracking provides a high degree of freedom and allow tracking in reality [8].
- The mobile eye tracker is worn like glasses, which avoids distractive influences on the user. It is minimal invasive and biases the users behaviour to a low degree.
- The scene video is recorded out of the user's perspective. By taking the first person view of a user the student can put himself in the user's position and see the interaction "though his eyes".
- In the scene video out of the first person view, the gaze direction of the user is visualized. Hence one can exactly follow the visual attention of the user during the interaction.

The analysis of mobile eye tracking data can be split up into the two categories, quantitative and qualitative analysis. The quantitative analysis is based on the eye tracking video with the user's gaze point included. By viewing the video students can put themselves in the user's place and take his or her perspective. Quantitative analysis uses the gaze data to calculate values, e.g. how often and how long a user looks at a defined area of interest. Both types of analysis are applied in the cases described in section 3.

Compared to questionnaires and retrospective interviews, mobile eye tracking records the user-product-interaction in real time, which is important since it is known, that user experience is a dynamic process and can be described afterwards, without the loss of information, hardly. Instead, these methods have a better comparability between subjects. However, user experience is a subjective phenomenon, which reduces the need of comparability. If comparing to observations from outside or concurrent interviews, which both can be recorded in real time, one can see that concurrent interviews biases the user strongly in his behaviour and observations from outside cannot provide such closeness to the user than a video out of the first person perspective. This comparison leads to the conclusion that eye tracking can bring out new and deeper insights for the understanding of user experience.

*Figure 1. Mobile eye tracking glasses with recording unit*

## 3 MOBILE EYE TRACKING IN DESIGN EDUCATION

In this section three cases of implementing mobile eye tracking in the educational context are introduced. In each case product and application are described before the investigations in user experience by mobile eye tracking records are shown. Finally, the integration of the user experiences in education is explicated.

### 3.1 Case 1: Power tool for direct fastening

#### *3.1.1 Product and application*

In the first case a hand held power tool for direct fastening is used as an artefact. The tool is intended for driving fastener nails into a steel surface. Therefore an explosion is created inside the tool, which accelerates the nail. It is developed for professional use in the construction industry.

Besides the main user-product interaction, which is driving nails into steel, there are secondary interactions between the user and the power tool during the lifecycle of the product. One example of such a secondary interaction is the exchange of the piston. Instructed users can operate this task, by themselves. Due to the fact that this is not a daily task, users normally do not know the proceeding of that action by routine.

#### *3.1.2 Investigation in user experience by mobile eye tracking records*

This case is set up in a laboratory in order to create a search task. The participants take part in this experiment, are no regular users of a direct fastening tool. They are equipped with mobile eye tracking glasses and asked to change the piston, without getting any instructions before. Hence the goal of this experiment is not to study the user experience of that specific case but to create a general search pattern, which often appears in different user-product interactions.

The analysis of the gaze path shows that the participants directly start to search elements in order to disassemble the tool and to find the piston. Figure 2 illustrates three captures of the mobile eye tracking video in a short interval of time (left: 46.83sec.; middle 47.50sec.; right: 48.03 sec.). Concerning visual behaviour one can see an explorative gaze pattern, with short visual fixation durations on multiple areas on the tool (skimming pattern [9]). By watching the eye tracking video the user's perspective can be taken easily and the visualized gaze path gives the observer the feeling of searching something as well.

#### *3.1.3 Awareness for user experience in education*

The eye tracking video is shown in a first years' design lecture (90min/week) to 450 mechanical engineering students. The integration of eye tracking into the lecture has two learning goals. First, the awareness for secondary user-product interactions, especially the relevance of product services and repairs should be raised. Second, the awareness for search patterns during an interaction, which indicates an unintuitive design, should be created. Knowing that this case is constructed, we however assume that search patterns appear in different applications with various artefacts and are indicators for product improvements. In the auditorium, the eye tracking videos creates a high attention by the students to the topic. We think that this is because students can take the user's perspective and see "through his eyes", which allows the students to feel closer the real user experience.

*Figure 2. Eye tracking video of interaction with power tool;*
*from left to right: sequence of gaze points (within 1,2 sec)*

## 3.2 Case 2: Electric bicycle

### *3.2.1 Product and application*

The artefact of this case is an electrical bicycle. With the so called “Pedelec” one can drive up to 40 km/h in flat area. The user operates the bicycle by turning the pedals as usual. The electrical motor supports the pedalling with additional torque, but only when the user moves the pedals.

The focus of this investigation is to understand the user experiences, when navigating in urban areas while cycling. For navigation to a defined place the application “google maps” has been used via mobile phone. As illustrated on the right side of Figure 3 the phone is fixed onto the steering rod by a prototyped holder.

### *3.2.2 Investigation in user experience by mobile eye tracking records*

The implementation of the mobile eye tracking glasses in this case aims to understand the users experience when navigating in an urban area, while driving an electrical bicycle. Three different drivers performed navigation tasks while wearing mobile eye tracking glasses.

The qualitative analyses of the gathered eye tracking data show a central finding, which was not expected in that dimension before. When looking at the navigation panel, the information which is lost concerning the driving direction, is immense. This bases on the time needed for understanding the navigation instruction on the mobile phone during cycling and on these kind of high velocities of driving.

### *3.2.3 Awareness for user experience in education*

This mobile eye tracking study took place in connection with a two and a half day ideation workshop. Master students as well as industrial partners take part in the workshop. The eye tracking videos shown in the workshop have been recorded in advance. Here the students act as users and drive the electric bicycle on their own, whereas they experience the product in reality. Afterwards, a qualitative analysis of the videos has been performed within the whole group of workshop participants by watching the eye tracking recordings and isolating users’ needs.

The awareness of user experience in the context of education is strengthened in two ways. First the students put themselves in the position of the user and drive the bicycle on their own. Second, they interpret their visual gaze path in the workshop. Comparing both situations the students realize, that the loss of information during cycling on their own felt much lower, than is shown by the analysis of the eye tracking data, afterwards. This study helps the students to understand the relevance of cognitive load and focus of attention of users when investigating in user experiences. If concentrated on a special activity the surrounding can be ignored radically and the subjective feeling can differ from a real measurement strongly (here: the time on the navigation panel). Furthermore mobile eye tracking recordings can uncover implicit facts and needs, the user is not aware of.

*Figure 3. Navigation task on electrical bicycle;*
*left: view on street; right: view on navigation panel*

## 3.3 Case 3: Peritoneal dialysis device

### *3.3.1 Product and application*

This case is extracted from a development project in the area of medical applications. Different dialysis therapies to treat insufficiently working kidneys were analyzed. One of the therapy forms is peritoneal dialysis, which is a renal replacement therapy. It better preserves the residual function and allows the patient to perform the therapy at home. The patients can apply the therapy, which requires the following actions by themselves. In the evening the machine, the connectors and the liquids have to be prepared before they are connected to the patient. Overnight the dialysis is working automatically. In the morning the dialysis equipment has to be disconnected and cleaned for its next usage through the patient or an assistant. In the project patients are visited at home in order to get an understanding of the user experiences with the application of peritoneal dialysis. The patients have been equipped with mobile eye tracking glasses and the whole procedure of preparation and connection has been recorded out of the patients' perspective.

### *3.3.2 Investigation in user experience by mobile eye tracking records*

The mobile eye tracking study has been undertaken with the aim of understanding the experiences of the patient, identifying his barriers, transforming these inputs into users' needs and creates proposals for product improvements. Especially, in a medical application, which make it hard to understand a patient as an external observer, mobile eye tracking records allow to take the patients perspective and learn how the medical therapy really affects a concerned person.

In this case a quantitative analysis of the eye tracking data is performed to subdivide the patient's application into sequences, in order to create a procedure-model of the interaction. In addition to that, object-related key performance indices are calculated, which are shown in Figure 4 on the right side. The numbers of visual fixations on defined areas of interest (display, disinfection and clamps) are compared. The evaluation of the data shows, that there is a low attention to the device and its user interface (low accumulate fixation duration on device and intuitive usage pattern). In fact, concerning visual attention the interaction with the periphery and secondary artefacts was the dominant factor in this user experience.

### *3.3.3 Awareness for user experience in education*

The eye tracking study including planning the experiments, recording the data, as well as conducting qualitative and quantitative analysis has been performed within a six month master theses. There are two central findings, which result out of the study. First, the importance of the context is very high, which is supported by qualitative and quantitative analyses. Not only focusing on the product and the user, but also on the surrounding as well as analyzing the user experience in the real environment are central methodical results of the study. Second, a deep understanding of the user experience over the whole application, including preparation and post processing is the basis for isolating the real needs and transforming them into product ideas. The awareness for the users experience as initial point of design and the relevance of the context is pointed out and understood by the students.


*Figure 4. Patient during peritoneal dialysis therapy;*
*left: gaze point on display, right: key performance indices of three areas of interest*

## 5 CONCLUSIONS

The aim of implementing mobile eye tracking into design education is to early raise the student's awareness for user experience. For this purpose mobile eye tracking has been applied to three different case based learning concepts to various extend. From a first year design lecture (case 1) over an ideation workshop (case 2) to a master theses (case 3) the degree of the implementation of mobile eye tracking increases. The more effort the students put in the recordings the higher is the awareness of the user experience. Table 1 summarizes the relation between the type of course and the kind of the implementation of mobile eye tracking as well as the student actions. The dark green fields show the kind of implementation in cased based learning concepts applied to the describes cases in section 3. The light green fields are other possible settings in general.

*Table 1. Overview of the implementation of mobile eye tracking records in design education*

| *implementation of eye tracking* | *type of course* | | | *student actions* |
|---|---|---|---|---|
| | design lecture (big classes, > 20p) | ideation workshop (small groups 3-20p) | master thesis (1-2 p) | |
| cases with general patterns | | | | comprehend |
| record data & qualitative analyses | | | | meet user, record, interpret |
| record data & qualitative analyses & quantitative analyses | | | | meet user, record, interpret, calculate |

The use of mobile eye tracking in education raises the awareness of user experiences. Especially the relevance of search patterns and secondary user-product interactions (case 1), the impact of cognitive load and focus of attention of users (case 2) and the importance of context as well as the understanding of the whole user experience as basis for isolating users' needs (case 3) are learned by the students, by mobile eye tracking analyses. In our view, the success of the implementation of eye tracking in education bases on multiple reasons. First, eye tracking hardware and software is easy to handle. Second, the records can be captured in the real environment with a low bias on the users' behaviour. Third the students can see the interaction with an artefact "out of the user's eyes", because the recording is in the first person perspective and visualizes the gaze direction. Finally the gaze videos considered as a teaching media have a high visualization power and take the students' attention.

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# REFLECTION IN DESIGN EDUCATION USING VISUAL TECHNOLOGY

**Einar STOLTENBERG and Vibeke SJØVOLL**
Oslo and Akershus University College of Applied Sciences

**ABSTRACT**
Product design students are trained to express themselves through visual media like two-dimensional (2D) and 3D drawing, prototyping, and digital media. Thus, written language is not always their first choice of communication. The aim of this study was to explore how multimedia can add to or broaden the scope within reflective work, and to identify the changes that may occur when product design students reflect through a visual and technological media like film instead of writing. Further, the disclosed findings are discussed through theory on reflection in education. The study was conducted via two workshops with product design students, participatory observation, and questionnaires. Sharing reflection through film introduced a different process to the students. One element was that the participants reflected in groups; this changed the process from individual to collective. Participants shared their reflections with others through both making and showing the film. Most of the students preferred filmmaking to written reflection, but the research also indicated that alternating between the two would be ideal. It was found that filmmaking increased the time and effort spent on reflection. Moreover, working in groups gave the students an arena to thoroughly discuss their discoveries and learn from each other. Exploring the potential of including several media adds to our understanding of reflection. As such, this paper sheds light on an alternative approach to reflection, and contributes a method of carrying out reflective work within design education and other educations using visual media and creative tools.

*Keywords: Reflection, Collective reflection, Filmmaking, Digital storytelling, Digital media*

## 1 INTRODUCTION

Reflection is one of the characteristics that constitute us as humans. The word “reflection” has Latin origins and is a compound of “*re*,” which means “back” or “back words,” and “*flection*,” which means “to bend” or “to turn.” In an educational context, reflection can be considered a process in which thoughts are “turned back” so that they can be interpreted or analyzed. In more familiar language, we often call this *looking back* or *looking again*. Thus, the focus then on the visual sense of seeing (looking) is apparent, and this leads us to the visual and imaginative aspects of thought. When thinking back, we use our imagination. According to Kaihovirta-Rosvik [1], *“Imagination is the faculty of imagining and the process of forming mental images or concepts. Imagination helps provide meaning to experience and understanding to knowledge. It is an apparatus through which people make sense of the world”* [1]. The exploration in this article will convey the role of visual language in reflection.

It has been a century since John Dewey published his theories of how we think [2]. The book discusses many ways of thinking, including reflection. In 1938, Dewey [3] defined reflection as: *“An active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and further conclusion to which it tends.”* According to Schön’s [4] description, reflection often takes form of a reflective conversation with a situation. Amongst others, a discovery of new levels in a situation emerges in this conversation. In addition, the conversation can reveal recognition of feelings a situation can evoke, consciousness of choices made and the grounds for them, and ideas and anticipations that help to address meaning [5]. In this conception, reflection is about learning from experiences, as Dewey [6] claimed. As Dewey [3] wrote: *“What (an individual) has learned in the way of knowledge and skill in one situation becomes an instrument of understanding and dealing effectively with the situation which follow. The process goes on as long as life and learning continue.”* It is important to emphasize that the mentioned writers all view reflection

as more than opinions on a theme or a situation. A reflective process should raise questions of a social, political, or cultural character and challenge assumptions and "certainties" that underlie practice [7, 8]. Boud et al. [9] defined reflection as a *"generic term for those intellectual and affective activities in which individuals engage to explore their expressions in order to lead to a new understanding and appreciation."* Through this, they emphasize the importance of feelings in the field, a notion that was elaborated on previously by Lindeman [10], who viewed reflection as a tool to start a process using knowledge, feelings, and experiences to understand and solve a problem. The process of reflection was considered a lasting and ongoing process by Schön [4] which he described as "reflection-in-action." In this way, he introduced the idea of reflection being not only a glance at the past on something that had been or was a retrospective process, but also an ongoing action to connect knowledge and practical experiences. John Sandars' [11] definition of reflection corresponds with Schön's view. He described it as a *"metacognitive process that occurs before, during and after situations with the purpose of developing greater understanding of both the self and the situation so that future encounters with the situation are informed from previous encounters"* [11].
Until recently, literature and research within the field of reflection almost solely considered reflection to be a written task. In an effort to make Dewey's thinking more accessible, Carol Rodgers [12] distilled four criteria from his writing. Her third and fourth criterion is of relevance for this article. Her third criterion is as follows: *"Reflection needs to happen in community, in interaction with others."* This is an interesting statement, as reflection is often performed individually. In Rodgers fourth criterion, she states that *"reflection requires attitudes that value the personal and intellectual growth of oneself and of others."* This shows that Dewey considered reflection to be more than a personal matter; rather, it should be done in interaction with others and be beneficial to others. This was later supported by Kemmis [7], among others, who referred to reflection as a social process, and by Vince [5] and Raelin [13], who argued for a shift from individual to collective reflection. The idea of reflecting in groups and sharing reflection is interesting. Over the past few years, the field of reflection has developed, and research and practice related to the creative use of digital media and storytelling has started to evolve [11]. In particular, digital storytelling has been invoked in this sense [11, 14, 15]. The Oslo and Akershus University College of Applied Sciences has run a project called Digital Storytelling for Learning [16]. In this project, they have among other things worked with reflections from practice. They describe a digital story as *"a short personal 'film' produced by the narrator. The story is supported by photos, (videos) and soundtracks. The editing is done in accessible and easy to use software."* The favoring of digital storytelling instead of film as a reflective tool is probably related to the openness and lack of professional pressure these new multimedia tools offer. The reflector needs less technical knowledge to create a digital story than is required for a film. Using multimedia containing elements like images, sound, voice, text, time, and animation in a film, opens new ways of expressing yourself. A multimedia approach can also inspire to make the presentation public, thereby sharing the reflection.

## 2 BACKGROUND

The research in this paper is based on two different workshops for two different second-year undergraduate product design classes. There were approximately 40 students in each class. The first workshop was arranged in 2012 and the second in 2013. The intention of the first workshop was to investigate the differences between written reflection and reflection through film. The second workshop's aim was to experience how students reacted to reflecting through film and to see if the findings corresponded with those of the first workshop. An additional aim for both workshops was to impart to students the importance of reflection and how it can change from individual to collective [5, 13]. To learn from experience [3, 6] is an important part of the learning process. In the learning outcomes defined by the European Higher Education Area, one of the skills a student should possess at the undergraduate level is the ability to reflect on his or her professional practice. This study explores the learning potential in reflecting through multimedia [11, 14-16]; this theoretical perspective could lead to learning outcomes of relevance for design education [17].

### 2.1 Research question

Product design students are trained to express themselves through visual media like two-dimensional (2D) and 3D drawing, prototyping, and digital media. The written language is not always their first choice of communication. To explore the benefits of using this knowledge within reflective work, we asked the following research question: How does the inclusion of multimedia affect the reflection process for product design students?

## 3 METHOD

The research question was analyzed through student projects [18], participatory observation [18], and questionnaires. The student projects involved two different workshops, where two different product design classes participated. The first workshop involved a combination of lectures, experiencing differences between text and film (digital multimedia story), and discussion in class. Meanwhile, the second workshop's focus was on students reflecting in groups [5, 8, 13] and expressing their reflection through multimedia. Here, the findings are discussed through theory on reflection in education [3, 5, 8, 11].

### 3.1 The first workshop

In this workshop, we particularly explored the issue of how reflection depends on the medium used in the process. This suggests that a reflection process will evolve differently and perhaps have different content with the use of different media. We wanted to determine what changes might occur in the transformation from text to sound and images. Thus, we tried to identify and discover these differences by changing a student's written reflection note into a film with images and voiceover. In the workshop, students first read a copy of a selected reflection note previously written by a student from another class. They were then asked to comment on it and give their opinion in an open discussion. The comments were written on a whiteboard to support the discussion. Following this, the students were shown a 2 minutes long digital story representing the course leader's interpretation of the same reflection note. After the viewing, the discussion procedure was repeated, with comments again written on the whiteboard. This was followed by a dialog where the aim was to locate the differences between the text and the digital story.

### 3.2 The second workshop

The main aim of this workshop was to determine how the students experienced reflecting through multimedia. It was conducted as a two-day workshop, were the students reflected upon the newly finished project they had worked on for the last two months. The workshop started with a lecture/discussion on reflection with a focus on why we do reflective work and how to do it through different methods. The students were given the task of reflecting through multimedia by creating a film or digital story. The students were used to reflecting through writing but had no previous experience in reflecting through film. Two digital stories were shown as examples of reflecting through a medium other than text. The students were encouraged to work in groups, and chose to do so. Through the workshop, we hoped to create a better understanding of how a different reflection method influences the reflective process and to determine whether it was a better way for product design students to reflect. At the end of the second day, the students presented their results in class. The workshop was analyzed through participatory observation [18] and a short questionnaire. The questionnaire was a mixture of selecting answers and writing down opinions and thoughts. All participants completed the questionnaire.

## 4 FINDINGS

### 4.1 The first workshop

As mentioned above, the students read through a reflection note and were asked to discuss it. Their first reaction was that they felt the reflection seemed dishonest, written with the aim of pleasing the teacher. However, not everyone in the class shared this impression. Approximately half of the students felt that the reported experience and insight was truthful and realistic. This led to a discussion of whether there should be grades given on reflection. The focus on truthfulness changed when the students discussed the digital story. They were clearly much more receptive to this experience, and did not consider it to be dishonest. They said that it was much simpler to understand, that it communicated directly and had a pulse. The digital story appealed to feelings through its use of sound and pictures. However, some students pointed out the use of special effects as something that could stray the audience's attention from the content and make it less critical or serious. Some students assessed the digital story in terms of how the effects of sound, pictures, and text communicated. These are all formal qualities that only reflect the content to a limited extent. They assessed it as a product, which may indicate a problem related to using this type of reflection in design education. This was a short workshop, and the findings required further investigation. This led to a second workshop where the students could experience reflection through digital media.

### 4.2 The second workshop

The general response from the students to reflection through film was very positive, and they felt it was an open and playful media compared to writing. There were even many comments on the workshop being fun. Most of the students (2/3) preferred this kind of reflection. The reflections were in general a bit less personal, lacking the complexity that may be expressed through written text. To share reflection through film changed the focus and selecting only one or two things to focus on became an issue. Because they had to choose and deeply discuss a limited area, some comments emphasized that reflection through film was a bit restricted. Nevertheless, having to make choices provided focused discussions between the students involved. In addition, there were several comments on the benefits of reflecting in groups, where the participants felt that they learned through the experiences of others. The film language opened up the possibility of using more senses. Several students felt that this led to clarification of how the message could be interpreted. The findings also showed that nearly all the students were against grades on reflective work.

## 5 DISCUSSION

A written reflection is usually not intended for sharing and going public. You normally write the note for yourself and maybe a supervisor. One major change from a written note to a multimedia reflection is that the results often become public, due to the multimedia's suitability for sharing. When group work is also involved, this turns into a social process and shifts from individual to collective reflection. Rodgers [12] emphasized in her interpretations of Dewey that reflection should be carried out in interaction with others and should be beneficial to them. As she wrote, *"[i]n isolation what matters can be too easily dismissed as unimportant."* This is a significant aspect when it comes to reflective films, which support sharing insight and understandings with others. When a film is created in small groups, the reflective dialog within the group offers possibilities to see things through different eyes and detect different meanings, which again might broaden students' understanding [12]. One student expressed that *"[i]t [reflective film] brings forth values which cannot be expressed verbally."* This might be due to the nature of visual and multimedia language, which offers a range of communicative and expressive facets that appeal to the use of several senses and the imagination. Imagination helps to provide meaning to experience and understanding to knowledge; it is an apparatus through which people make sense of the world [1].

The idea of engaging in social and collective reflection to enhance learning has been put forward by several researchers [5, 7, 8, 13]. When working in groups and displaying reflection publically, the student/practitioner is no longer communicating the message from only his or her perspective; instead, other people and cultural codes are included, thus adding dimensions to the reflective situation. This, in turn, could lead to the intensification of the reflection. On the other hand, its public nature might affect the direction a creator takes in making the film such that he or she maintains some privacy. As one student noted, *"You are not very personal when you know everyone will watch it."* On the other hand, another student conceived this public element of film very differently: *"One of the best things was that we did it together with someone, which made it possible to discuss and talk about what we had learned. Being several people together made it easier to be honest."* Apparently, the students had different perceptions concerning how personal and honest a digital multimedia story could become. Exposing feelings is a personal choice and differs from student to student. It is also the possibility that strong individuals within a group may dominate the reflective process. This indicates that the best way of reflecting will differ from individual to individual. This assumption is confirmed by Sandars [11], who claimed that the method of reflection should be determined by the individual, since different individuals will prefer distinct approaches.

Some felt that reflection through digital media was limited because they had to focus on only a few elements and could not express a very detailed account of the experience. They also worried that the teachers did not get the same insight into their thoughts and understandings through this form of reflection. However, this only reveals a misconception concerning reflection in this context. In our opinion, the primary point of reflection is for the student's own sake and his or her fellow students. This attitude could be representative of some students' belief that reflection is for showing the teachers how insightful they are rather than for their own learning. In contrast, we consider the part of the process where the students discuss their experiences and insights to be most important, with the finished result being of lesser importance. Nevertheless, the presentation of the result is important when it comes to learning from each other and sharing insight. Moreover, it is important to know what the students know in order to adjust the content of teaching. Still, we agree with the students that it should not lead to grades on reflective work. Both workshops indicated that if the reflection notes were to be assessed summatively, many students would write what they thought the teachers wanted to read and not what they had actually experienced. Thus, the students nearly all thought that reflection should be assessed formatively. This view on assessment corresponds with Biggs' [19] claim that *"[t]o use it for both formative and summative purposes, as may happen in continuous assessment, creates a conflicting situation for the students: they are being asked to display and hide error simultaneously."*

The findings showed that many of the participants found the workshop fun and entertaining. One student stated, *"it was a fun way to do it, because it allowed creativity."* This indicates that the students were pleased that they were able to use their specific skills and interests in order to carry out reflective work. Several of the movies from the workshop used humour as a communicative element. Normally, we are not used to students referring to reflection as fun, and it was clearly motivating for the students to approach it in this way. On the one hand the workshop was a good experience, and the positivity of the participants indicates that this is a good way to carry out reflection in product design studies. However, we also question if the lightness in attitude the students expressed may have affected the depth and quality of the reflection. A couple of the students also wondered if it might be less serious compared to writing. This might be due to writing and theory traditionally being perceived more scholarly and serious than making images or other visual sensuous communication. One of the findings in the first workshop was that some students believed the use of special effects in a video could distract from the content and make the result less serious. It can be a challenge to convince some students to give serious presentations in public. Probably because some feel it is difficult to express feelings and due to their wish for making a film that impresses others on a technical and entertaining level. There is no doubt that design students have achieved skills through their study, which is an advantage when working with film. On the other hand, they also take great pride in delivering a well-made "product"; this could lead to the students spending more time on creating a well-made film than on their reflection. One student who claimed to have concentrated *"more [...] on techniques and less on reflection"* confirmed this assumption. Moreover, although reflection through digital stories has been used with great success in several disciplines [11], it is possible that students who were less inclined toward creating digital stories, for example, fields outside of design education where multimedia creation is not a focus, would put less pride into their "product."

As mentioned above, two-thirds of the students preferred reflection through film. Some wanted a variation between the two, and only 10% preferred written reflection. One student stated, *"Reflection is often something one writes at the last minute because it is 'just writing.' Multimedia forces you to spend time on the reflection."* However, the questionnaire used was limited in relation to this issue. The students had to choose between written reflection and reflection through film. Some marked both options, indicating that alternation between the two would be ideal. Using visual technology represented a variation from how our students usually carry out reflective work. If expression through film were the rule and writing the exception, the results may have looked different. Sandars [11] claimed reflection should be something one does before, during, and after a project. This was not achieved through the method presented here, and for instance, a combination of writing a log and reflecting through film would probably lead to better learning. As a result, the student would engage in holistic reflection, reflecting through the whole process writing notes, and benefit from social and collective work using visual technology.

## 6 CONCLUSION

This paper shed light on an alternative approach to reflection and contributes with a way to do reflective work within design education using visual media and creative tools. The learning outcomes from this study are related to both skills and general competence. Skills are related to the ability to reflect on one's own and others' practice. General competence is about conveying insight through relevant methods of expression. Using group work and multimedia in a reflective process within product design education emphasizes other qualities than those we find within written work. For instance, filmmaking increases the time and effort spent on reflection. Both film and written text can involve the aspect of storytelling, but with film, multiple senses are involved. Working in groups gives the students an arena in which to thoroughly discuss their discoveries and learn from each other. The students are able to use their technological, aesthetic, and visual skills in this process. On the other hand, because design students take pride in their visual work, it can be a challenge to get some students to take the reflection seriously enough and stay focused at a cognitive level. It is easy to be seduced by visual effects and get lost in the enormous choices and potential within the medium itself. The temptation to create a well-made film might distort the reflective process.

This method of reflection was new to the students and was found to be very popular; however, it might have been conceived differently if they used this method every time they reflected. Further research is needed to evaluate this possibility. The multimedia approach that we used in this study was in many ways a successful way of reflecting on process, but was limited when it came to reflecting before, during, and after the process [11]. As mentioned in the Discussion section, it is likely that alternating between writing and using multimedia would be ideal. Further research into this assumption would be an interesting development of this project and could represent a possible aim for a third workshop.

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# ANTHROPOMETRICS 2.0: ENRICHMENT OF CLASSICAL ANTHROPOMETRY THROUGH MULTIDISCIPLINARY COLLABORATION

**Stijn VERWULGEN[1], Daniel LACKO[1,2], Guido DE BRUYNE[1], Femke DANCKAERS[2], Naomi CHRISTIS[3], Jan SIJBERS[2] and Toon HUYSMANS[2]**
[1]Product Development, Faculty of Design Science, University of Antwerp, Belgium
[2]iMinds-Vision Lab, Department of Physics, Faculty of Science, University of Antwerp
[3]AnSyMo, Department of Mathematics and Computer Science, Faculty of Science, University of Antwerp

**ABSTRACT**
State of the art computational methods might offer the opportunity to handle 3D anthropometrical information: in a collection of similar 3D shapes, when there is a correspondence of points, certain mathematical operations, such as calculation of mean shape and even a standard deviation in each point, can be performed. As such, a statistical shape model can be interesting for the purpose of product development since it provides insight in the intrinsic variation of a 3D form within a given population and-if large enough- even contains all information to determine the shape of each individual, making statistical shape models potentially very interesting to design mass customization products. To that end, the information contained in statistical shape models should be made available for the purpose of product development, to enrich the classical use of anthropometry in the design process. The intended enrichment is further denoted "Anthropometrics 2.0". This concept was first explored through a multidisciplinary collaboration with master students in Product Development, Computer Science and Applied Engineering, supported by the Belgian industrial research and development conglomerate (BiR&D).
The objective of this educational project was to explore how state of the art statistical shape models could be made available as digital models for the purpose of product development through CAD. In this paper we present the results towards this aim and how the different scientific disciplines with respective master student collaborated towards this purpose. The project was confined to the human head.

*Keywords: Anthropometry, statistical shape models, CAD, multidisciplinary collaboration*

## 1 INTRODUCTION

No two humans have the same body and the average human does not exist [1]. This makes designing products that optimally fit the human body a challenging task. For years, 1D anthropometric measurements such as height, width and circumference have been used to anticipate the necessary customization for near-body products. However, since these measurements do offer only very sparse statistical information, several iterations of user testing and feedback integration are often required. 3D statistical shape models could offer a solution for this problem [2]. Shape models consist of 3D geometric surfaces with a large number of corresponding points [3]. This makes it possible to combine classic 1D measurements with a detailed local and global analysis of shape variation for various body parts. In theory, this enables designers to generate and compare realistic shapes using intuitive anthropometric parameters. Several studies have shown viable methodologies for this purpose [4], some of which have developed preliminary tools for designers [5]. However, it has never been demonstrated to work in real-time in a contemporary CAD environment that is familiar for the users.
One of the reasons for this is the inter-disciplinary nature of the problem. On the one hand, computer scientists or mathematicians are needed to perform the statistical analysis and create the initial 3D shape models. On the other hand, the shape models need to be incorporated into a CAD-environment. Lastly, they need to be evaluated by the end users, i.e. product designers.

This educational project set out to realize a proof-of-concept for a statistical shape model of the human scalp, created during the PhD of Daniël Lacko [6]. The shape model was created from a sample of 100 MRI-scans, from which the skin layer was segmented and the region of interest was selected based on a manually determined boundary. The skin surfaces were then corresponded (see figure 1), PCA was performed to find the global and local variations and the correlation between the PC weights (see figure 2) and seven anthropometric measurements was examined. It was found that the global shape of the human scalp could accurately be predicted using these measurements as parameters.

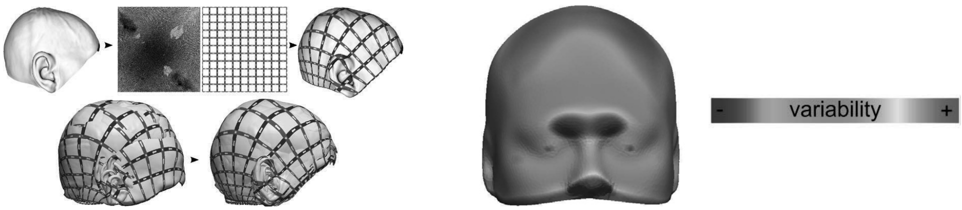


*Figure 1. Building of a statistical shape model from medical images (left): a collection of head forms is retrieved from MRI images, annotated and mapped to coordinate grids, and aligned. As a result e.g. a mean shape with the variation at each point can be visualized (right)*

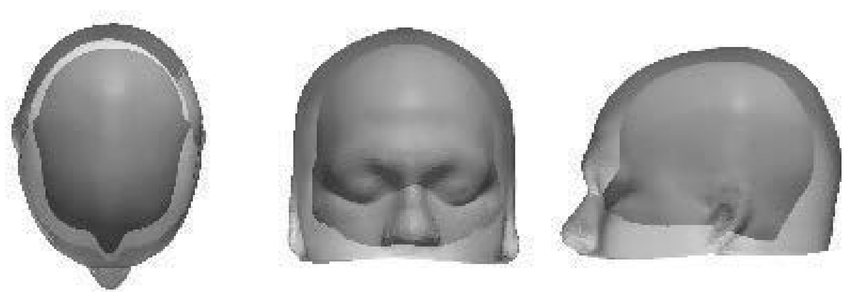

*Figure 2. Mean head with first principal component added +3 and - 3 times standard deviation [7]*

The goal of this project was to implement this parametric shape model in a CAD software package by recruiting an interdisciplinary team of students. The hypothesis was that their combined skillset would make this ambitious goal possible. Students from the fields of Product Development, Computer Science and Applied Engineering were selected and each was expected to perform a specific part of the implementation for their master's thesis. The Applied Engineering student was asked to automate and improve the segmentation process, in order to make adding new scans to the model more efficient. The student from Computer Science was to create a plug-in for CAD software in which the shape model could be interacted with in real-time. The Product Development student's assignment was to evaluate the user interface and user experience of such a plug-in and to create a simple head-mounted design using the shape model. Each student was guided by an expert in their specific field, as well as by the team that created the original shape model. The students were encouraged to collaborate as much as possible and to clearly communicate their work process and results to each other.

## 2 MATERIALS AND METHODS

The project was conducted with the support of the Belgian Industrial Research and Development fund (BiR&D) that stimulates multidisciplinary collaboration to enhance industrial relevance of research and educational projects. Three research groups of the University of Antwerp worked together: Vision Lab (Physics), Cosys-Lab (Applied engineering) and Product Development, each group guiding a respective master student from Computer Science, Applied Engineering and Product Development.

The aim of the project was to make state of the art statistical shape models available for the purpose of product development by building a CAD environment in extension to anthropometric distributions and existing digital mannequins.
For the CAD environment there was opted to use SolidWorks© due to expertise by the participating student as well as by the supervising team, access to consultancy, and availability of licenses.
Each of the students started along the initial project plan of the BiR&D proposal that was written by the supervising research teams, starting with an initial literature study required to execute his or her task in the project and further acquisition of additional tools and techniques during the course of the project. In addition, students made a detailed project plan to assign individual tasks and responsibilities. Head shapes of an ongoing PhD research [6] were incorporated in SolidWorks© and each model was accessible for an individual design. The outcome was an intuitive parameterized CAD model of the scalp shape. As such, a parameterized design could be constructed. The use of the enriched CAD environment as a tool for additive manufacturing was verified through designs and rapid prototyping and communicated by the development of a demonstrator case.
The project team was guided in regular meetings around major milestones: kick-off, implementation plan, intermediate progression, mid-term review, anthropometric model implementation, plug-in operation and final presentation. Each student presented his of her progression, followed by feedback from the project team to discuss further steps, synchronization of deliverables and to enhance mutual understanding. Information was exchanged by file sharing (Dropbox), electronic communication (email) and telecommunication (cellphone and Skype). In addition, students where followed up by their respective domain specific (co-)promotor complemented by other members of the supervising team, if required.

# 3 RESULTS

## 3.1 Contribution from computer science

The student from computer science wrote an extensive overview of relevant mathematical theories and techniques: statistical shape modelling, fitting of a cloud of points with B-splines, principal component analysis, linear equation solving, matrix decompositions and linear feature mapping. She got acquainted to the basics of SolidWorks© and mastered all software required for the successful realization of the SolidWorks© plugin.
The plugin was tested using the statistical shape model of an ongoing research project, consisting of 105 surfaces retrieved from medical images and 7 standard anthropometrical measurements already annotated: *head length*, *face width*, *bitragion width*, *ear height*, *horizontal position of the ear*, *vertical position of the ear* and *projected ear height* [7], further denoted "the anthropometric model".
However, it is possible to use other input databases for improved accuracy, for example with an extended number of shapes and/or additional anthropometrical measurements. By using a uniform mathematical entity such as a B-spline, the designer becomes able to define useful and clear geometrical relations between an individual's surface and its digital design and hence can produce smart designs suited for mass customization.
Computational complexity was managed by clever use of mathematical properties such as linearity of principle component decomposition [8] and linearity of the anthropometric model, the use of sparse matrices, good linear equation solving techniques and maximal use of affine invariance of B-spline fitting.

## 3.2 Contribution from computer applied engineering

The student from Applied Engineering first performed a preliminary study on the techniques to detect and correct artefacts (e.g. holes and spikes) typically arising in CT, MRI and laser scans, using an underlying statistical shape model to reconstruct the original shape, such as Poison reconstruction [9], model and elasticity regularization [10].
She implemented and compared three error correcting algorithms based on a given statistical shape model that, at the same time, extend the statistical shape model with the corrected shape: a first fitting strategy where the shape model is regularized, a second fitting strategy where the elasticity parameters of approximating forms are regularized and a third, combined technique. The input data of her algorithms are: 1) a shape of the human head possibly contaminated with artefacts, for example an outer surface extracted from an MRI scan and 2) a statistical shape model of similar but

uncontaminated forms. The output data of her algorithms are: 1) a proposed reconstruction of the original shape and 2) a correspondence of the reconstructed shape with the shapes of statistical shape model.
The shape reconstruction was validated for artefact removal in numerical experiments with dramatic holes in the skull, as shown in Figure 3. Thereby the model regularization (left) and combined strategy performed equally well, where elasticity regularization (middle) is unsuitable, mainly due to an inherent problematic alignment in the initial step of the algorithm.

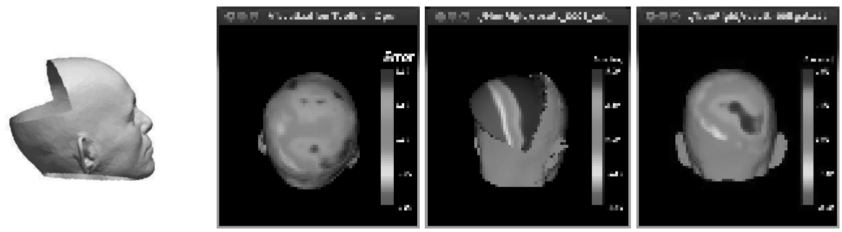


*Figure 3. reconstruction of missing information in head shapes (left) with three shape reconstruction algorithms*

### 3.3 Contribution from product development

The student from Product Development focused on the merits of statistical shape models when used in a regular product development process, as described e.g. in [11]. Firstly, relevant economic and technologic factors concerning the intended implementation and intended use of statistical shape models in CAD were explored, to end up with the specifications for a CAD environment enriched with information retrieved from statistical shape models. Secondly the actual plug-in developed by Computer Science was verified by designing artefacts that ought to closely fit the human head (Figure 4) and by building prototypes of these artefacts. Verification was done with physical models realized with a Dimension 1200 3D printer with an accuracy of about 1/4th of a mm. The student designed the model displayed in figure 4 (left) on his own head, on an image retrieved from an MRI scan. A very good fit was achieved. Furthermore, a method to validate the representativeness of the database with rapid prototyping was developed: screws in model were used to measure variations in the band from glabella to ophistokranion (at points A, B, C in the middle of Figure 4) and a measurements in 8 test persons holt indeed magnitudes predicted by the statistical shape model (Figure 4 middle).

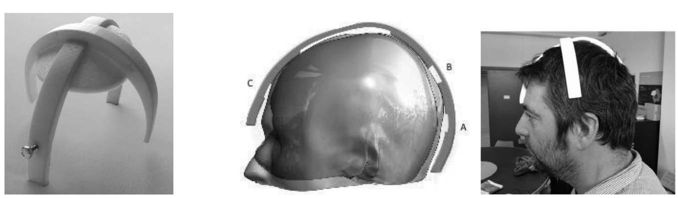


*Figure 4. An instrument to measure variations on the human head (left) developed as a personalized design for and by the student, and points that were measured (middle right) by other subjects Stijn Verwulgen, right)*

The band from glabella to ophistokranion was mapped on the head shape models of Daniël Lacko and Stijn Verwulgen (Figure 5), retrieved from the same batch of MRI images and fitting was physically verified through 3D printing.

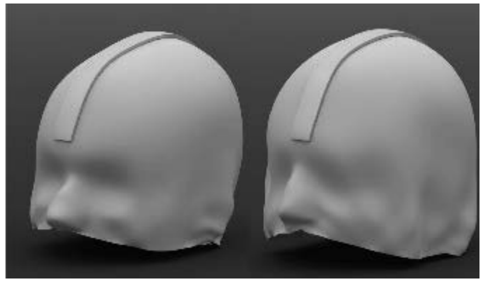

*Figure 5. Personalized form following the models for the heads of Daniël Lacko and Stijn Verwulgen*

In addition, the student constructed a demo to communicate the idea of a parameterized design based on the human head. In his example displayed in figure 6, on the left the design is seen: the device on top and on the left and the right are tailored to an individual's head whereas the bended bars have a fixed form and size. When the head shape is altered e.g. by reducing the length value of the head, the most probable corresponding shape is automatically rendered together with the respective personalized design (Figure 6 middle and right).

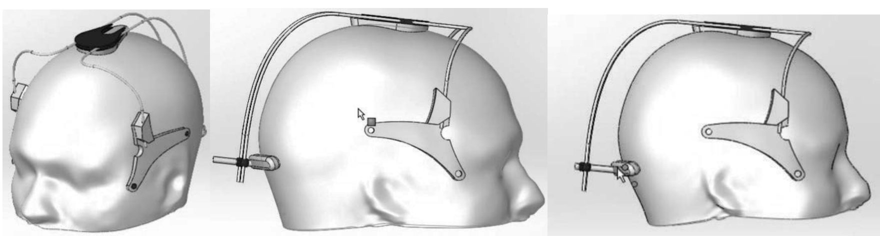

*Figure 6. Demonstrator case of a personalized design*

## 4 CONCLUSION

The inter-disciplinary team succeeded in developing a CAD plug-in for anthropometric shape modelling. Despite the strict time constraints, the plug-in could be used to create an elementary individualized head-mounted design for two supervisors.

The student from Computer Science wrote a plug-in to make statistical shape models of the human head and the anthropometric model available in an enriched CAD environment for the purpose of product development. The software was verified with an input database of 105 models and 7 standard anthropometrical measurements. The input database can be extended if additional shapes or feature data becomes available to refine the models in the enriched CAD environment. She is currently pursuing a PhD in an unrelated field.

The application is still in early development, yet it gives a good indication of the functionality of designs that are directly parameterized on the human body using straightforward anthropometrical measurements as parameters. Though the software is currently only available internally, the project managed to arouse interest from the industry and resulted in a BiR&D award (http://www.birdbelgium.com/call2012). Funding for further research on PhD-level has been awarded in the form of an IWT-TETRA project "CADANS: A CAD Platform for 3D Statistical-Anthropometric Design" (IWT ref. 130771). This project will be executed by a multidisciplinary team of product developers and computer scientists.

The student from Applied Engineering constructed an artefact removal algorithm that allows for an efficient automated reconstruction of original shapes, directly from medical images, thereby omitting labour intensive extraction of representative images by hand on an individual basis. The algorithm allows for an efficient extension of current statistical shape models concerning automated shape reconstruction and yields a promising approach towards automated acquisition of anthropometric

measurements. She is now continuing her work in a PhD at the Vision Lab of the University of Antwerp.
The student from Product Development identified specifications for an enriched CAD environment based on statistical shape models. The current implementation was tested for design for additive manufacturing by the design of demos and verified with rapid prototyping, followed by recommendations for further improvements. He is currently employed in a paid internship in Spain.
These results clearly show the added value of interdisciplinary collaboration in education. Universities benefit from additional research projects, which might otherwise not have been realized. The industry benefits from clear applications and possibilities for further collaboration with universities. Finally, but perhaps most importantly, the students benefit from the broadening of their knowledge, get a first taste of different academic research fields and can add an ambitious project to their résumé.
The results of this project at master level have revealed the potential of a new design technique that has been further developed through research. Moreover the project serves another educational purpose: results have been presented to master students in product development, as an invitation to use the new technology in their design projects.
The authors therefore encourage other universities to employ master or even bachelor grade students for the integrated validation of research projects from different fields, with a focus on the development of new design techniques.

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# APPLICATION OF VR TECHNOLOGY IN DESIGN EDUCATION

**Hailu GEBRETSADIK, Vikramjit KAKATI, Amarendra DAS**
Department of Design, Indian Institute of Technology Guwahati, Guwahati

**ABSTRACT**
In the era of globalization, design education is playing vital role in design of products and systems. Designers conceive products which are in their imagination and many a times these are virtually prototyped but need to be converted into tangible products. Design education is facing the challenge of teaching theory and application to bridge the gaps between solution of a design problem and its conversion to a tangible product. Virtual prototyping facilitates to visually realize the size and form of a product and physical products can be realized through Rapid Prototyping (RP). However the product may require further modifications in absence of haptic feedback during virtual prototyping process since designers may not be able to perceive characteristics such as textures, elasticity, weight, depth, perception etc. Advancement in three dimensional visualization technologies and increasing demand for innovative methods in design education has made it imperative to use wide range of teaching and training materials involving virtual environments. Virtual Reality (VR) technology provides with realism and interactivity. The VR technology with haptic device integrated with Virtual Prototyping may reduce the gap between imagination and reality of virtual prototyped model, which can provide reality like perception of the conceived products and significantly enhance practice based teaching in design education and learning experience. If VR can be successfully combined with CAD to provide haptic feedback, space and form perception, it will bridge the existing gap to some extent between imagined/conceived and tangible products realized through RP.

*Keywords: Virtual reality, design education, virtual environment, education, technology*

## 1 INTRODUCTION

Current 'Industrial Design' and 'Engineering Design' students are entering higher education with significant computing knowledge and higher expectations from academic institutions that introduce them to appropriate technologies for their successful transformation into industry. Due to those reason, academic institutions are challenged to adopt appropriate strategies to meet the innovative educational demand [1]. In addition to this, industries are challenged by their customer's requirement, since customers have more focus on the ergonomic characteristics (e.g. comfort, appearance, texture, ease of use etc.) of the products. These characteristics of product are generally adopted at the early stage of product design, which consequently affect the manufacturing process and products performance. Thus, virtual reality and augmented reality technology are appropriate to speed up and give the wide option in a decision making activities in early stage of design process. VR has enormous potential to help in visualizing and understand the complex concepts and theories, lead to new product design, to motivate and encourage designers/design instructors in immersive three dimensional environments for teaching learning and design practice [1, 2]. Virtual reality is being used for industrial design, military training, automotive and aerospace design, medical (surgery, dental, and for phobia & autism treatment), maintenance, repair, and entertainment [1, 3, 4, 5, 6]. Virtual reality also provides a suitable environment for design reviews helping to reduce the development time and costs and to improve the quality and usability of new products. Above factors has made it almost compulsory for VR to be integrated with design education curriculum to be globally relevant. This requires design application based research in this domain. This research is in this direction undertaken by doctoral research scholars, where actual application of VR is used to evaluate product performance in terms of various ergonomic characteristics e.g. comfort, appearance, texture, ease of use, weight of the designed product etc. Particular product considered in this research is a battery powered tea leaf plucking machine designed in-house in the Department of Design [7], IIT Guwahati by doctoral research scholar forming a part of design education to evolve a proper methodology for VR application in Design education.

## 2 AIM AND OBJECTIVE

Until recently, most of the applications of VR research are associated with design, entertainment, maintenance, repair, military & medical training purpose, product evaluation, educational tool applied for the science, art, mathematics etc. while limited information is available on its use as design educational tool. The aim of the present research work is to highlight existing scenario of VR applications in design education sectors for various purposes such as interior design, product design, ergonomics studies, and usability by integrating with haptic devices which allow interaction with virtual model and sensing the object with more realism. An attempt has also been made to highlight advantages, as well as identified reasons behind less adoption of this technology in design education disciplines. Aim of this research work was to evolve a method that can be easily adopted by design students and thereby facilitate integration of VR in design education.

## 3 VIRTUAL REALITY AND ALLIED SYSTEMS

### 3.1 Virtual Reality

Virtual reality has been defined in many different ways with respect the context of use, in general Virtual reality defined according to William and Craig [8] as a medium composed of interactive computer simulations that sense the participant’s position and actions and replace or augment the feedback to one or more sense, giving the feeling of being mentally immersed or present in the simulation (a virtual world). This may display inside a blank room, headset, or other device that allows the user to feel present in the virtual environment [9]. Some virtual reality also offers features like feedback in the form of sound or touch to allow the user to interact with objects and spaces. As it is known, during the product design development, usability tests are usually performed after the physical prototype; now with the integration of CAD-VR with the haptic feedback device during the product design development process it allows to test and evaluate the usability without incurring cost for prototyping [10]. Haptic technology provides new potentials by allowing human operators to interact with digital models using the sense of touch. This aims to develop methods allowing designers to feel the elasticity of the products and to test the function of products with a haptic interface.

### 3.2 Augmented Reality

Augmented reality is a technology, which seeks to enhance the virtual reality environment by integrating the real world with added virtual elements. These can include sounds, sensations, or images generated by a computer system. Augmented Reality brings virtual information or object to any indirect view of user’s real world environment to enhance the user’s perception and interaction with the real world [11]. Unlike virtual reality, augmented reality does not create a simulated reality. Instead, it takes a real object or space and uses technologies to add contextual data to deepen students' understanding of it.

### 3.3 Virtual Prototyping

It is process of getting digital out put that represent the imagined model of component or system to be constructed during design process. Virtual prototyping (VP) has great advantage for decision making and modifying the weaknesses during the design stage. The use of physical prototypes is more expensive, they take longer to finish and difficult or impossible to modify it [2, 12]. Tactile feedback is the basis of these applications, in which the need for natural interaction and for the prototype to obtain the same features and properties as the real products, are emphasized.

## 4 APPLICATION OF VR AND AR IN DESIGN RELATED FIELDS

There is no doubt that usage of VR technology has brought avant-garde changes in many multidisciplinary scientific fields including design education. As large number of the authors have agreed that VR and AR are important and has potential in visualizing and interacting abstract model in three dimensional contexts and to facilitate learning. VR/AR provides the natural and interactive ways to express ideas and overcome the technical gap in the iterative design process by upgrading from traditional computer aided design process to mixed reality aided design space [13]. In addition to this, Ye et al [12] investigated and explored the potential of VR based technologies into a computer aided product design and evaluation in comparison with traditional techniques. The uses of VR applications in various design education related fields have improved the productivity of teaching and training by allowing engineers to apply theoretical knowledge to real industrial problems with real time experience [1, 14]. The VR is categorized in three different kinds, first is desktop VR, which is by far better, most common and least expensive form of VR; second, a semi-immersive VR system that attempts to give the users a feeling of being at least slightly immersed by a virtual environment and third form of VR is usually referred to as being fully immersed [15, 16]. Desktop VR provide real time visualization and interaction within a virtual world that closely resembles a real world and enhances the learning outcomes [1, 17]. The real time interaction with virtual environment could be achieved through several communication methodologies such as visual (computer screen or stereoscopic display), tactile (force feedback) and auditory (stereo sound) feedback [18].

Nowadays applications of AR are widely used. Unlike other computing technologies AR supplements (combines) the real world with virtual objects (i.e. computer-generated) [19]. The combination of AR technology with the educational content creates new type of automated applications which acts to enhance the effectiveness and attractiveness of teaching and learning process for students in real life scenarios. Actually, AR is a new medium which is combining aspects from ubiquitous computing, tangible computing and social computing. This medium offers unique affordances, combining physical and virtual worlds, with continuous and implicit user control point of view and interactivity [11]. Using AR systems learners interact with the 3D information, objects and events in a natural way. Billinghurst [9] used AR technology in education for support of seamless interaction between real and virtual environments and suggested educator to work with researcher in exploring how this can be applied in school environment. Another interesting application of AR technology is to develop augmented reality textbooks [11], in which books are printed normally but when a webcam is pointed over the book, it brings visualizations and designed interactions on the screen of the device. This is possible by installing special software on a computer or mobile apps on a portable device. This technology allows any existing book to be developed into an augmented reality edition after publication. Through the use of AR in printed book pages, textbooks will became dynamic sources of information. In this way, people can have a rich interactive experience with comparatively less computer knowledge than computer experts.

## 5 HAPTIC INTERACTION WITH VIRTUAL MODEL

Haptic is the technology of adding the sensation of touch and feeling to computer generated models. This technology allows computer generated virtual objects to be touched and manipulated with one's hands or body [10]. Haptic senses links to the brain's sensing position and movement of the body by means of sensory nerves within the muscles and joints. Haptic feedback information is combination of tactile and kinesthetic information. Tactile information refers to the information acquired by the sensors connected to the body and kinesthetic information refers to the information acquired by the sensors in the joints [20]. In the context of virtual reality applications, haptic is a tactile feedback technology which allows users to use their sense of touch while interacting with a virtual model. By using haptic devices, users can interact with a virtual model by feeding and receiving information through tactile sensation. The possibility of interaction between the user and virtual models extended for Usability evaluation supports designer's decision making that evaluates design appearance (such as the texture, hardness and shape of objects) of product, and reduce revision cost of an inappropriate design, and save time [10,12].

*Figure 1. Haptic interaction with Virtual model*

## 6 APPLICATION OF HAPTIC FEEDBACK DEVICE AND VR IN DESIGN EDUCATION

There are certain problems of VR systems which are not integrated with haptic feedback devices. These problems include lack of depth perception, lack of perception of tactual properties etc. of the virtual prototype while designing in a virtual environment. Due to this fact designers/ design students may not able to develop appropriate product prototype for rapid prototyping. Therefore, repeated rapid prototyping is required for taking decision about ultimate product that will be manufactured further. Thus, this ultimately leads to increase of cost of rapid prototyping as more rapid prototype need to be developed for taking ultimate product decision.

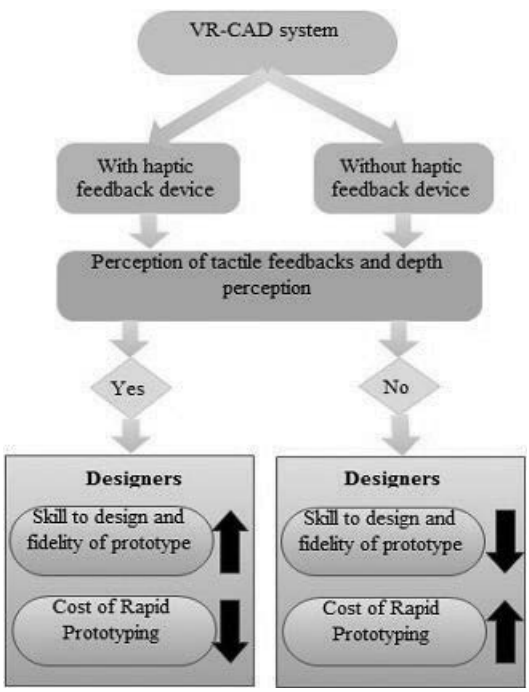


*Figure 2. Flowchart the impact of VR with and without haptic on Prototyping*

In **Figure 2,** it was depicted how designer may rely on the integrated VR-Haptic system to gain the skills of virtual prototype development and fidelity of the prototype. **Figure 2** is also able to express the importance of tactile feedback and depth perception during prototype development. Actually, haptic feedback system enhances virtual prototype fidelity which ultimately leads to less number of rapid prototyping as well as cost reduction for rapid prototyping. With the present conceptualized frame work, it is clear that this kind of system may have some impact on design process. Therefore, design faculty may use this kind of system to teach prototype development to their design students for better design outcome. For instance, usability of the virtual model of tea leaf plucking device (**Figure 3**) may be evaluated with VR-Haptic feedback system such as "PHANToM Omni Haptic" which is enabled of tactual feedback as well as depth perception. In this evaluation process it is assumed that VR-Haptic integration will be helpful tool to reduce cost of prototyping, and time to market.

## 7 METHOD

Authors of this paper have initially studied state of the art in VR application through several research articles, review papers, books and book chapters from various authentic search engines with the help of internet as well as books available in library. The search engines used for this present review include Google, Google Scholar, ACM digital library, IEEE Xplore and other digital libraries. Following thorough study of the available literatures findings were reported systematically.

Based on the study, a method was evolved for using VR in design education as a tool by design students. Design of experiments were undertaken to validate the method evolved by actually taking a virtual prototype in CAD model and evaluating and improving the design prior to actual prototyping. VR program was formulated to evaluate and improve a prior Virtual Prototyped CAD design of a tea leaf plucking machine, **Figure 3**. Improved design was physically prototyped in both formats, prior to application of VR and after application of VR. Physical prototypes were tested in actual use and during the process it was found that physical prototype arrived after VR application was better than the one prior to VR application as assumed and thus a bridge between imagined model and tangible model was possible in terms of design experience.

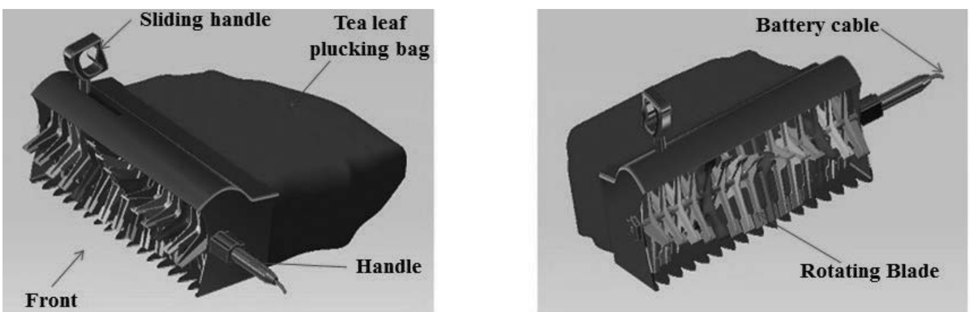


*Figure 3. Battery operated Tea leaf plucking virtual model*

## 8 SUMMARY AND CONCLUSION

This paper briefly discussed about VR and AR technologies and their applications in various design related fields. In addition, present paper also able to discuss about the benefits of integration of haptic feedback device into the VR systems as well as how this integrated systems would help designers/ design students to perform realistically in complex computer aided product design process.

In the recent past, very limited researchers have applied VR/AR for design education. Although, these cutting-edge technologies have potentials to transform and improve design education in various purposes such as interior design, product design, ergonomics, usability engineering, form and shape design etc. by integrating with haptic devices which allow interacting with model and sensing the object with more realism and interactivity. This kind of system may be helpful for students to develop better understanding of complex CAD systems and design process. As stated above that application of these technologies to design education is still in its infancy. There is an urgent need for creating general awareness about benefits offered by these technologies for their wide adoption and very user-friendly methods for VR application by novice designers. There is a need for creation of awareness among tutors, researchers, scientists, engineers, etc. and could be achieved through organizing seminars, conferences, workshops etc. based on actual application case studies as described in this research work.

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# HOW UNIVERSAL DESIGN PRINCIPLES CAN ENHANCE THE INTERFACE OF 3D PRINTING PROGRAMS

**Linn STEEN-HANSEN, Maud Veronica Gine LUNDH and Weiqin CHEN**
Department of Computer Science, Faculty of Technology, Art and Design, Oslo and Akershus University College of Applied Sciences, Oslo, Norway

**ABSTRACT**
Experts have predicted that 3D technologies will take on a growing importance in the economy. Results from a previous research in a Norwegian College indicate that the use of 3D modelling programs and how intuitive students in Product Design feel they are depend on the students' previous IT knowledge. It also showed that teachers and students are interested in using 3D printing in Product Design education. The study presented in this paper focuses on how Universal Design (UD) and usability principles can enhance the interface of 3D printing programs. A heuristic evaluation has been conducted on a 3D modelling program, Rhino, using a set of guidelines based on theories from usability, universal design and product design process. The evaluation uncovered serious issues in the interface. The study concludes that UD and usability principles can contribute to creating more intuitive and user friendly interfaces in 3D modelling programs and enhancing the effectiveness of rapid prototyping which leads to more iterations and flexibility during the design process.

*Keywords: 3D printing, universal design, heuristic evaluation, Product Design education*

## 1 INTRODUCTION

Higher education should provide equal opportunities for all students regardless of background and abilities. However, technological innovations often create barriers. One example is in Product Design Education. The students need well-developed 3D printing programs to facilitate their learning and design process. Use of 3D printing for product designers is important on several levels. Common 3D-printers could represent the future for manufacturing businesses [1] and production overall. The technology can also give a new role for the Product Designers [2]. However it is important that the focus remain on the design process. These programs are mere tools and should be easy to use for anyone, be it someone with low IT-literacy, someone with dyslexia or even a blind or motor impaired person. A case study on the use of 3D printers in the library of Dalhousie University uncovered that printing 3D models which were designed by users with no knowledge of how the 3D printing worked was a challenge. Many flawed STL files illustrated a serious problem with providing a 3D printing service to students inexperienced in using this technology. The study concluded that a large learning curve needs to be addressed and 3D printing needs to be complemented by demonstrations and instructional seminars [3]. Interviews with students of Product Design uncovered that some participants did not use 3D printing because the program interfaces was too difficult [4]. This paper investigates how Universal Design (UD) and usability principles can be used to evaluate a popular 3D printing program and uncover its usability problems in order to enhance the interface design. The focus is on what technical problems exist in the system and how these can be addressed through the use of the seven principles of UD and Nielsen's 10 heuristics.

## 2 3D PRINTING

Prototyping and testing is an important part of the traditional design process. Different methods for prototyping can be used in this process. Among these is exploration of form with paper, cardboard, plastic materials etc. Mock-ups can be made for discovering form and functionality. Functional and/or aesthetic models are meant for describing the function of a product. Lastly there is the prototype; a visually correct and functioning model. For prototyping, 3D printing can be ideal to use since the model/prototype is lightweighted, fast to print and install. However, the computer programs used need to be accessible, efficient and user friendly. In this research we focus on the usability and accessibility of Rhino. Rhino (Rhinoceros 3D) is a stand-alone 3D modelling software developed by Robert McNeel & Associates. Rhino's popularity is based on its diversity in use, many multi-disciplinary functions and its flexibility to import/export over 30 different file formats. Therefore it is possible to use Rhino as a conversion tool between programs. In addition, Rhino claims to have a low learning curve [5].

## 3 BACKGROUND

An interview was conducted by the authors in autumn 2013 with four master students in Product Design. During the interview the participants were asked about their use of 3D modelling programs in their design process. Two of the participants said they did not use 3D printing because the program interfaces was difficult to use. They felt they needed to improve their skills to use it effectively. All the participants felt they should know about 3D printing before entering the job market and were very interested in additional coursing. This was partly because they thought that 3D prototyping often can be more effective than traditional methods of prototyping. It makes it easier to quickly make small changes in the product before and after user testing which allows more iterations. This study uncovered that use of 3D modelling programs and how intuitive they felt depends on previous IT knowledge. It also concluded that Universal Design can contribute to the development of more user friendly and accessible interfaces in 3D modelling and printing programs used in Product Design education [3]. It should also be noted that some of the participants were not particularly familiar with computer interfaces in general and might have benefited from a more self explanatory interface. This might also minimize the resources needed for coursing, demonstrations and instructional seminars.

## 4 METHOD

A heuristic evaluation of Rhino has been conducted using a set of guidelines adapted from Nielsen's heuristics [7] and the seven principles of Universal Design [6]. The evaluation was conducted with the educational context in mind. Student's points of view gathered from the interviews in 2013 were considered when applying the heuristics. The Centre for Universal Design at North Carolina University prepared seven principles for UD in 1997. The principles aim at UD in buildings, public spaces and technology (hardware and software) [6]. However since 1997, the principles have not been updated to better suit today's technology or aim for websites, applications etc. Jakob Nielsen developed 10 heuristics that aimed directly at software production that can also be applied to websites. These heuristics are broad enough to apply even though the technologies have drastically changed [7]. Here we map Nielsen's heuristics with the seven principles (Table 1) in order to create a new set of guidelines (Table 2) which are more suitable for producing and/or evaluating software, websites, applications etc. It is a goal that this new set is simpler to apply and suitable for a wider range of technologies than existing guidelines such as Web Content Accessibility Guidelines (WCAG). Compared with WCAG the guidelines are not so comprehensive and complicated. They are also not so technical, making them relevant for designers and consultants in addition to developers. Compared to the seven principles of UD are the guidelines more updated and focused on software design.

*Table 1. The mapping of the seven principles of UD and Nielsen's 10 heuristics*

| **The seven principles of Universal Design** | **Nielsen's heuristics** |
|---|---|
| 1: Equitable in Use | |
| 2: Flexibility in Use | 7: Flexibility and efficiency of use<br>1: Visibility of system status |
| 3: Simple and Intuitive Use | 2: Match between system and the real world |
| 4: Perceptible Information | |
| 5: Tolerance for Error | 3: User control and freedom<br>5: Error prevention |

| | |
|---|---|
| | 9: Help users recognize, diagnose, and recover from errors |
| 6: Low Physical Effort | 4: Consistency and standards<br>6: Recognition rather than recall<br>8: Aesthetic and minimalist design |
| 7: Size and Space for Approach and Use | |
| | 10: Help and documentation |

*Table 2. New set of guidelines*

| Top level criteria | Second level criteria |
|---|---|
| The system should be simple and intuitive to use | • The system should speak the users' language (clear language/simple English)<br>• The system should use a standardized language, consistent in the system<br>• The system should use intuitive icons and colours that are not cultural or demographically limited |
| The information should be perceptible to anyone | • The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities<br>• The systems technology should not create compatibility barriers that can change or hide information for the users |
| The system should be flexible and efficient to use | • System should provide a choice in methods of use<br>• System should accommodate right or left hand access and use<br>• System should facilitate the user's accuracy and precision<br>• System should provide adaptability to the user's pace<br>• System should show user system status |
| Error handling | • System should tolerate error without crashing<br>• System should help user prevent errors<br>• System should help users recognize, diagnose, and recover from errors<br>• System should have a clearly marked "emergency exit"<br>• System should have room for version control in case the users makes mistakes or the system crashes before saving recent changes |
| Help and documentation | • System should be self-explanatory, but big, complicated programs will always need help and documentation<br>• The system should have open for support in form of e.g. email, forums, and videos |
| The system should be equitable in use | • System should provide the same means of use for all users: identical whenever possible; equivalent when not<br>• System should avoid segregating or stigmatizing any users<br>• System should make sure that privacy, security and safety are equally available to all users |
| The system should demand minimum effort | • The system should let the user recognize instead of recalling to minimize memory effort<br>• Dialogues should not contain information which is irrelevant or rarely needed<br>• The system should support keyboard access so the user |

| | |
|---|---|
| | can switch between using different input methods |

## 5 FINDINGS

The system, as a whole, was evaluated on each criterion. This also made it possible to uncover if some of the guidelines were redundant, which they were not. Because of time limitation, only an overall evaluation focusing on the standard toolbar version was executed, as highlighted in Figure 1.

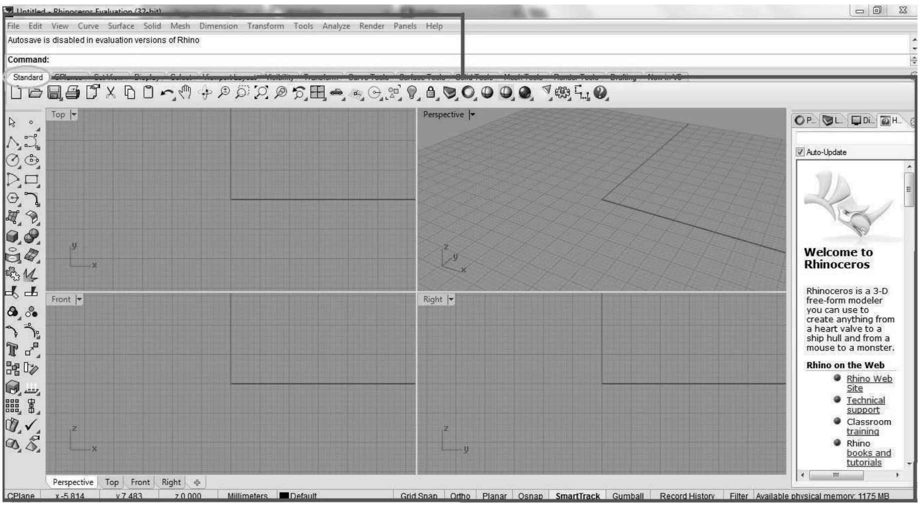


*Figure 1. Screenshot Rhino desktop*

### 5.1 The system should be simple and intuitive to use

As a first impression the desktop seems cluttered with many icons and text with no further explanation of usage. There is a left menu that contains functions presented as icons. The icons are a mix of unfamiliar icons and icons commonly used in similar tools. Furthermore there are four toolbars; two top, one right, one left, which seems like too much. The left menu is cluttered, making it difficult to distinguish each function (Figure 1). It is also debatable if these icons are intuitive for product designers, but this needs user testing. The two top menus offer to some extent the same functions, making it redundant. However the text and icons are more common and intuitive in these menus than the system in general, e.g. the save-icon and “file” part of the menu. It is up for debate whether younger people know what a floppy disk is and whether it is a common icon for the save function. For a person who is not familiar with any modelling software the system will seem confusing, cluttered and not intuitive. The tool does contain a consistent language and the labels used are common in modelling software. However, the labels might be difficult since they are only in English and demands IT-literacy. The language should be changed so it uses more familiar words for designers and does not demand much IT knowledge.

### 5.2 The information should be perceptible to anyone

The users will not lose any necessary information due to compatibility problems against varying conditions or the user’s sensory abilities versus the tool’s design. Such ambient conditions are more due to different screens and light settings on hardware level. However the design relies much on grey nuances making it difficult if the light in the user’s room makes the screen dark and difficult to distinguish the design. This could be avoided with better use of contrasts. Another issue is that the users can not personalize colours or contrast. Allowing users to personalize colours or contrast would make the system more flexible for users in situations such as when light on the screen creates a barrier. The tool is on a software level making it more flexible in theory for assistive technologies like screen readers etc. However compatibility barriers often depend on the individuals working habits and flow. To uncover other serious compatibility issues a larger user test is needed, not only to find possible barriers, but also to map all the possible ways to use the tool.

### 5.3 The system should be flexible and efficient to use

The tool provides various ways and choices to design a 3D model. It is also possible to remove or add different menu panels, change colours, font-size, font-type etc. This is done under preferences and here the navigation is complicated and the sub-menus do not explain properly what kind of options is offered. To change e.g. background colours, a lot of guesses were made before finding the right menu. There is also no way to change the placement of the panels that accommodate better right- or left-handed use. The tool facilitates the user's accuracy and precision by making it possible to use drawing tools like mouse or touch pen. The system does not have any time restriction making it possible for the users to work at their own pace. The tool presents system status through text either in a dialog field or through popup boxes. The different menu panels also contain redundant functionality. To enhance the efficiency and minimize memory efforts for different actions, the design should be stripped for all redundancy and it should be only one panel to offer modelling functionality, one panel to offer overall system functionality e.g. save or open file. A last panel should only include documentation.

### 5.4 Error handling

During the evaluation, errors were deliberately made by the tester trying to crash the system. This did not happen. An attempt to use too much RAM caused the tool to freeze, but after a while the issue resolved itself and no work, even unsaved, was lost. However, when wrongly shutting down the computer without saving, Rhino did not give any status of the sudden shut down and what happened to the files. Note that this may be due to the use of an evaluation version of the software. Also because of this possible limitation it is not noted any possibility for a version control or help for the users to recognize, diagnose, and recover from such errors. The system gives feedback when the user attempts to overwrite an existing file and closes before saving the recent changes. The software has the usual window exit marked with an X-icon which is seen as intuitive.

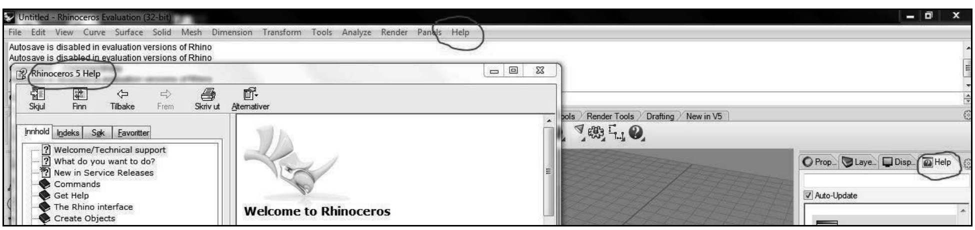


*Figure 2. Screenshot of help options*

### 5.5 Help and documentation

The tool has a documentation panel to the right that offers help and possibilities to learn more. This help section links to Rhino's official website, but also offers offline documentation internally in the system. The documentation panel is cramped and the design is too complicated for such small space to be efficient and simple to use. In addition, when using some of the navigation links in this panel a popup window over the panel opens with more documentation. If using one of the links in this popup, it will close using the origin help-panel showing more documentation. This is somewhat confusing. There is also a help sub-menu at the top menu bar giving links to the same places of help, but some are in different format, e. g. a popup window giving the same information as the help panel (highlighted in figure 2). All this makes it confusing when trying to find help in Rhino and questioning what is different and/or best to use between all these options. The website also offers support in form of email, forum, user community and phone calls.

### 5.6 The system should be equitable in use

To check if the system provides the same means of use for all users: identical whenever possible; equivalent when not, user testing is more suitable than expert testing. The tool is neutral in icon use, language, and colours, avoiding stigmatizing. Users with approved license get equal privacy and thus security and safety considering users personal and credit information.

### 5.7 The system should demand minimum effort

The tool supports keyboard navigation as well as mouse and pen. There are few dialogues and those contain information about the system status, action confirmation, and the documentation panel. The tool is redundant in functions and documentation, making the overall system architecture more complicated than necessary. Many functions are also hidden behind sub-menus making it more difficult to remember where to execute the different actions and prompting the user to recall rather than recognize through icons. User testing should be conducted to validate these issues.

## 6 CONLUSION AND FUTURE WORK

This paper investigated how Universal Design and usability principles can enhance the interface of a 3D printing program, Rhino. The goal was to uncover possibilities for making the system easier to use, thus shifting students' focus from learning to use the program to using the program as a tool in Product Design education. The combination of universal design principles and usability heuristics allowed us to identify problems in different aspects of the interface, such as ease of use, error handling, flexibility and access to help and documentation. The findings indicate that implementing the combined principles could to some extent aid in making a more user friendly interface, which would better support the activities in Product Design education, such as the transition between 3D printing and materialisation evaluation, handling errors in the 3D printing process, and visual documentation for creative form development. Moreover contrary to the low learning curve claimed by Rhino [5], findings from our evaluation indicate a high learning curve and low accessibility and usability, may have severe consequences for students using the system. Future work may include a survey among Product Design students to confirm the general issues with the Rhino interface. In addition, user testing with a heterogeneous group of users with different backgrounds and capabilities could uncover issues beyond those found in the heuristic evaluation. Additionally, in order to provide support and guidelines to software professionals so that Rhino and other 3D modelling software can be more accessible and usable a prioritized list of principles could be valuable.

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## Chapter 3

# SOCIAL ASPECTS OF DESIGN EDUCATION

# POLITICAL ACTION AND IMPLICIT KNOWLEDGE IN ENGINEERING EDUCATION: A CASE OF STUDY.

**Sergio BROMBERG**[1] **and Viviana POLO**[2]
[1]Universidad San Buenaventura Cali – Faculty of Engineering
[2]Universidad San Buenaventura Cali – Faculty of Architecture, Arts and Design

**ABSTRACT**
The educational act is a political act, where information and data are just a fraction of what should be taught. Indeed, there has been much literature on the subject of promoting creativity, teamwork, management, communications, and ethics (so called "soft-skills") in engineering curricula. This knowledge might be as important as technical knowledge. Some authors report experiences where this issue has been approached by incorporating specific courses on these subjects in the curriculum. This strategy belittles the role of the implicit curriculum in addition to explicit curriculum. The Multimedia Engineering program at Universidad San Buenaventura - Cali, a blend between engineering, design and the creative arts, is a program where these skills play a particularly important role. First, in the sense that creativity is a fundamental component in arts, and second, in the sense that the program's graduates will be responsible for the future uses of technology, and as such they should be aware of their role of promoters of social change. Through a case-study in the development of a robotic-art installation, we suggest that teamwork, ethics, and emotional knowledge are better "taught" through an implicit curriculum and that "soft-skills" may not be that soft. Structural changes in the educational act, including physical spaces, number of students per teacher and class duration may be needed to implement pedagogical models that incorporate these skills.

*Keywords: Engineering education, teamwork, heterarchy, political duties, collaborative programming*

## 1 INTRODUCTION

There is a well-documented need for incorporating so called "soft skills" such as interdisciplinary teamwork, management, communications, ethics, problem solving and creativity in engineering curricula. Their importance is such, that they are now called "21$^{st}$ Century skills". Moore and Voltmer [1] state that "the increase in "required" technical material has resulted in the neglect of creativity and imagination in many programs" and that "emerging engineers must recognize their role, not merely as developers of new technological systems, but also as educated, informed, and ethical servants of society with a higher purpose". Scheer et al. [2] state that pedagogical models that incorporate these aspects have been difficult to implement, and suggest Design-Thinking as a framework where they can be "learnt". Nearly all engineering programs state that their ultimate purpose is to serve to mankind by the use of applied scientific and technical knowledge. Many works deal with incorporating sustainability issues in engineering curricula, though these changes may be slow [3]. The promotion of civic values in engineering is addressed by Liu [4] by using service-oriented real-world projects in class. The approach from Liu is a good example of service-learning in software engineering. Apart from social commitment, new curricula should allow students to develop non-technical competences, and let them unfold their personality [2]. Pair programming has been shown to increase not only quality but confidence in the students own work [5]. Felder [6] argues that "even more important than providing exercises in creativity is making students feel secure about participating in them. Most of us learn early that being wrong is unacceptable and looking foolish is even worse, and these lessons are reinforced throughout our lives". Therefore, interaction in the classroom acts in emotional ways in students, but this is rarely taken into account when designing engineering curricula.
The Multimedia Engineering program at Universidad San Buenaventura - Cali is a new undergraduate program that shares elements from computer science, electronic engineering, creative arts and design. The program aims at creative uses of technology, specifically in their potential for transforming society. Therefore, the incorporation of the aforementioned skills is necessary. Curriculum-wise,

computer science/engineering is very different from the creative arts. Engineering curricula have a strong science (mainly mathematics and physics) basis, followed by applied engineering (often called "professional") courses. Some programs also have courses focused on management and entrepreneurship. While many programs include elective courses on social sciences and ethics (especially in confessional universities), their impact in a graduate's professional life is questionable and students often regard them as non-relevant. Teamwork is occasionally used in final projects of engineering courses, but entire courses devoted to team-projects are seldom.

Development methodologies from the creative arts and design field are also different. If not a major component, most multimedia engineering projects involve programming at some point of their development and therefore software engineering methodologies may be used as a model. While some software development models are more flexible than others, they differ from methodologies in the creative arts and design. Users may become spectators, and functional requirements may become expressive requirements (communicate an idea), or end requirements (e.g. "promote bicycle use in urban areas"). In the arts and design fields, conceptual basis has a more balanced relation with technical development.

Curriculum wise, the blend between engineering, creative arts and design is a challenge, but also an opportunity to reshape the way engineering students relate to technology. In 2013, the GTA (*Grupo de tecnología para las artes*) group worked in a robotic-art collaboration. The fact that it was an art project with a strong engineering component, makes it a good illustration of pedagogical dilemmas in multimedia engineering. In the following, we will use it as a case study for analyzing the importance of non-technical knowledge in engineering education and its implementation in the curriculum.

## 2 THE SYMBIOSIS PROJECT

The Symbiosis project was a 5-month collaboration between *Precarius Tecnologicus* and the GTA group. The GTA is led by one of the authors of this text and integrated by 6 multimedia engineering students, four of which participated in the project. The aim of the installation was to build a set of vegetal-robotic organisms that would illustrate and question the symbiosis between nature and technology. Robots would provide the locomotion for a plant in its need of water and light. The project had a schedule with encompassed a research stage (roughly one month), a prototyping stage (one month), a development stage (programming and building, two months), and a testing and set-up stage. The group would meet most of the time in the artist's studio on a weekly basis, though in the final stage of the project several day-long sessions were needed in order to meet the deadline. After the art exhibition, the students held a 20-hour workshop on robotics to 18 peers. The group held two wrap-up meetings in which the project was evaluated.

### 2.1 Results

After the design stage, the group decided to make a series of hexapods with a Raspberry Pi brain and 18 servomotors that would live in a constrained space. The insects would carry the plant in their back and take it to a watering place. For their spatial awareness, a custom computer-vision application would be programmed, which would send the robots position data (acquired by a camera on top of the pen) via Wifi. While solar energy was considered for powering the robots, requirements of both the Raspberry Pi and the servomotors demanded for batteries.

The project revealed interesting aspects about both technical and non-technical skills in engineering. It was a real-world project, and therefore with little tolerance to failure. Students devoted an approximate of 8 hours per week to the project in its beginnings, but near the deadline their dedication more than tripled. The collaboration was mostly extracurricular, and therefore the students would not be graded. Despite this fact, students showed an unprecedented commitment with the work being done. In the wrap-up meetings, all participants stated that the project was the most enriching experience along their studies and that they had learned more by working in the project than in a standard course. As it was a project outside the curriculum and the total hours that students dedicated to the project was not counted, a proof of this statement cannot be provided.

Interdisciplinary work with the arts was important in several senses. The participants were able to spontaneously assume their roles or tasks according to their experience or interests. The work, as a real-world art project, had both a technical and documentation requirement, providing a good example of students' future professional life. The scope of the project was broad enough so that all participants had to learn from each other, promoting respect towards other students' opinions.

From a technical point of view, several issues arose. Students agreed that they had very often chose difficult solutions when problems appeared during the project. In a few cases where ready-made solutions were available the group decided to program their own solutions (e.g. programmed vs. ready-made computer vision software, RaspberryPi vs. Arduino boards). This fact led the group to devote more time to technical aspects, than to conceptual aspects, and was eventually a mistake. The group agreed on the fact that the initial design was not achievable in the time that was proposed, and changed servo-motor locomotion with geared motors. While this can be accounted for a lack of research, the authors state that engineering students often have technical goals instead of conceptual goals. Their projects are often conceived in terms of the tools that they involve, rather than in the message they convey, or their overall functionality. This may be so because both students and teachers have been trained in out-of-context situations where they have to implement a tool or use a technique for the sake of learning it and not with a particular purpose.
From a non-technical point of view, the relationship between students and teacher was much more symmetric than in a standard engineering course. While the teacher did play a leading role in the group, students were free to choose many solutions to problems and eventually inverted the knowledge flow as they "taught the teacher" about tools they had learnt. Close to the deadline, the group had to work in several day-long sessions, which enhanced the cohesion of the group. In this sense, space was also important. Day-long and night-long session could not be held in the installations of the university, as there were not any permanent spaces where the group could leave their hardware for several days. A workshop on robotics was conducted, as one of the project goals was also to transmit to peers what had been learned during the process. During the workshop, the students of the group assumed the role of instructors. Assistants to the workshop were both teachers and students from other engineering programs. The workshop was not only a good way of replicating what was learnt, but also a way of building-up self-confidence in students.

## 3 DISCUSSION

Education, from its different physical and virtual scenarios provides explicit and implicit languages, tools and elements, which act as variables in the teaching and learning process. Explicit language refers to formal instructions by the teacher about how work has to be done, specific knowledge about the subject that is being taught, and its purpose. Implicit language refers to the mechanism by which intangible habits and attitudes are learnt from the teacher. For example, a teacher may be used to solve problems with daring and novel approaches, however, his attitude towards problem solving is probably learned by students implicitly, and not by telling students to "please be daring". Personal attitudes from the teacher may be passed on to students via an implicit way. Also, the nature of the interaction between the two may generate new attitudes. As an illustration, the teacher may not be fearful himself, but he may build-up a fearful attitude in his students because of an authoritarian form of interaction. Explicit contents (mostly technical in the engineering case), as well as implicit contents transmitted by a symbolic meta-language, complement themselves to conform knowledge. The Symbiosis project was an opportunity to examine both of these aspects. There was a great deal of explicit knowledge into play (robotics, electronics, computer vision, biology). However, as the group did not have experience in all of these fields, the process was not a standard unidirectional teacher-to-student learning process, but rather a process where knowledge was jointly constructed. From a pedagogical point of view, the learning *process* was therefore as important as the *contents* being learnt. The management of these implicit channels demands also a big responsibility, as it may be more prone to convey moral, political, ethical and emotional knowledge than the explicit channel. We state that however they are called, multidisciplinary teamwork, creativity, communication skills, etc. are learnt in non-explicit ways, and that greater awareness of this fact (mainly by the teacher) is necessary to achieve effective learning experiences. *Learning experiences* are indeed a good metaphor about where new curricula may point, as they stress the fact that learning is a holistic process. Some successful case studies [7][8], suggest that structural changes in the classroom are a good start. Indeed, the Symbiosis project held important structural differences with standard classroom interaction: open spaces where team-members could both interact among each other or work individually; permanent spaces that the team felt as "their-own", accessible at nearly any time; a low students-per-instructor rate. Structural aspects of classroom dynamics may be studied through social network analysis, of which case studies are provided in [9]. Interaction structures in the classroom should hold more similarities with real-world cases. Students and teachers are singular, therefore, interaction structures should respect these singularities by being more symmetrical (while conserving the role of the teacher of orienting problem solving). Dialogue and respect for the peer's opinion are essential in classroom communication. As stated by Dewey "every experience enacted and undergone modifies the one who acts and undergoes, while this modification affects, whether we wish it or not, the quality of subsequent experiences" [10]. We suggest that more symmetrical structures in the classroom may extend to other scopes, ultimately fostering democratic values in society. In this sense, intervening curricula is a political action.

Traditional pedagogical models are hierarchical. These models are centered in decisions coming from the teachers. An engineering curriculum that changes this structure, makes the student visible as a political subject, in the sense that it constructs a heterarchy. This concept has been defined previously in anthropology and can be extrapolated to sociological and pedagogical areas. According to Crumley: "Heterarchy may be defined as the relation of elements to one another when they are unranked or when they possess the potential for being ranked in a number of different ways [11]". These new structures are can be thought of as knowledge interaction networks where "value is amplified when there is organized dissonance about what is valuable. We do better when more of us with varied voices ask this question from different standpoints of what is worthy" [12].

## 4 CONCLUSIONS

Many authors have stressed the need of incorporating non-technical skills such as multidisciplinary teamwork, ethics, communication, creativity and curiosity in engineering curricula. These skills are particularly relevant for a multimedia engineering program, as it is a blend between engineering, design, and the creative arts. Effective learning experiences must balance them with technical skills. A case-study on an interdisciplinary robotic-art installation showed that students find these experiences more enriching both technically and emotionally than standard courses. Furthermore, we suggest that these skills are more prone to be experienced implicitly than explicitly, through interaction with peers and teachers in real-world collaborative projects. Both implicit and explicit strategies should be thus incorporated in pedagogical models. I this sense, structural changes that modify interaction patterns inside the classroom may be needed for achieving effective learning.


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# A PARTICIPATIVE AND SOCIALLY INTERACTIVE APPROACH TO THE TEACHING-LEARNING PROCESS IN INDUSTRIAL DESIGN

**Juan Carlos BRIEDE WESTERMEYER[1], Marcela MORA[1], Jorge CARTES[1] and Marcela PÉREZ[2]**
[1]Universidad del Bío-Bío, Concepción, Chile
[2]Universidad del Desarrollo. Concepción, Chile

**ABSTRACT**
Industrial design is concerned with meeting social needs, providing users with products that improve their quality of life. The Industrial Design program at the University of Bío-Bío in Concepción, Chile promotes this aim by offering a "User-centred design" (UCD) workshop for third-year students. The DCU workshop uses project-based learning, and employs a methodology that takes the user as its starting point, shifting the paradigm from "designing for" to "designing with" the user. In 2012, design students joined a collaborative project led by the non-governmental organization "Un Techo para Chile" (TECHO), benefitting low-income families living in state-housing projects in the Nonguén Valley. This initiative focused on developing practical solutions to residents' needs by involving them in product design. Participation in both decision-making and co-creation provided a space of trust and confidence between design students and community members which emphasized the social responsibility of designers. This project culminated in the production of pragmatic design solutions that successfully met local needs and ultimately improved the quality of life for residents.

*Keywords: Design Education, Participative approach, social integration*

## 1 INTRODUCTION

Chile, one of the southernmost countries in Latin America, is characterized as a developing economy committed to reducing poverty and improving the quality of life for its citizens. Higher education is one important tool for achieving this change, as it directly impacts the economic and social standing of all members of society. The Biobío region of Chile, where this study was conducted, is an industrial zone with one of the highest levels of poverty in the country. Consequently, a number of governmental initiatives have emerged in order to address persisting inequality and to increase overall social inclusion in the region. Academic institutions have also served this aim by providing an education that fulfils a uniquely social role: enrolling disadvantaged populations and emphasizing the social impact of students' work. The University of Bío-Bío in Concepción, Chile is one such institution that uses this educational model to impact society on multiple fronts.

The relationship between higher education and employment, especially in the field of design, is not well known, and there exists an ongoing need to develop effective strategies that help design students transition to the labour market following graduation. Design education has traditionally used a projective methodology to guide the learning process [1], wherein students are encouraged to reflect on work experiences as moments of situated learning [2]. Project-based learning is also widely employed as a way for students to supplement theoretical knowledge acquired in the classroom [3]. The Industrial Design Program at the University of Bío-Bío incorporates project development into its curriculum. Such activities focus on building competencies [4], where the combination of technical skills and the knowledge needed to perform a given task [5] allows students to generate new applied knowledge [6][7].

This competency-based approach to learning helps with student insertion into the labour market. Throughout the five-year design program, students are exposed to various levels and types of interventions geared towards observation, production, clients and business. Students also develop social skills relevant to their profession, which allow them to respond appropriately to the needs of their environment [8].

The present study looks at the role of design in solving social housing problems. It analyzes houses provided by the Department of Housing in Chile (MINVU) that are designed to meet the basic needs of residents. Measuring at approximately 40 $mts^2$, the houses have two bedrooms, one bathroom, a small kitchen and a living space that includes a dining area and living room [9]. Nonetheless, they do not provide optimal conditions for carrying out housework, nor do they offer spaces for storage, clothes drying or waste management, etc. Moreover, furnishing options on the market are not sufficient or accommodating to the small size of these properties. As a result, many residents have turned to creative measures in developing partial and inadequate solutions.

Within this context, students of the University of Bío-Bío conducted a field study, assessing living conditions and evaluating problems in order to develop solutions together with community members. In doing so, students utilized a participatory approach that focused on social interaction, encouraging the participation of community members in the detection, evaluation, selection, co-creation, testing and approval of solutions. Attentive to the complexities of working with vulnerable communities, students joined hands with the Centre for Innovation of TECHO [10] in order to explore the role of design in creating value, and to better understand the role of designers as social agents [11]. The initiative involved beneficiaries of a social living program [12] from the same organization who are based in the Nonguen Valley.

The present intervention was designed to show students how the interplay of factors, such as social behaviours, social systems, cultures and sub-cultures, determine a given client and ultimately shape the ways in which designers should respond. In providing quality solutions to a largely neglected population—low-income communities at the base of the pyramid (BOP)—student efforts not only met the needs of disadvantaged and excluded groups, but also provided these groups with dignity [13].

## 2 CONTEXT

### 2.1 Initiatives for Social Integration

The work carried out by TECHO has propelled a number of student collaborations, allowing students to volunteer on housing projects targeted at those most vulnerable—from providing emergency shelter to developing solutions that address thematic challenges for students— and which meet social needs. These projects even extend to popular education workshops which seek to build capacity among residents in establishing income-generating activities. One such workshop led by Social Lab [14], and in collaboration with students, utilizes an online platform to encourage social enterprise. This project seeks to address conditions of extreme poverty by understanding the problems faced by socio-economically vulnerable families, and therefore creating opportunities for social innovation. Overall, the project acts as a motor of social integration, looking beyond the notion of social assistance to provide residents with control over their own communities.

The collaboration between the University of Bío-Bío and TECHO provided students an opportunity to work directly with a local community—not to simply gather information, but to experience, to put into practice, and to value and understand the role of social skills, such as communication and empathy, in carrying out long-term projects [15]. It is ultimately this set of skills that allows students to understand the complexity of working with human beings. Industrial design education should thus respond to the need for a more comprehensive and humanistic perspective, focusing not only on teaching core concepts, but also core behavioural and social skills that allow students to reflect on the human dimension of their work [16].

### 2.2 Methodological Context

User-centred design locates the user as the centre, beginning and end of the design process [17]. Web applications, for example, consider the user as a key player in the process of evaluating, suggesting, and even designing aspects of applications [18]. If we apply this to product design, we can see a number of methods available for registering, systematizing, and utilizing the perspectives of users [19].

The User-centred design workshop (UCD) at the University of Bío-Bío employs this focus by developing products which respond to the specific needs of users [20]. It considers the design process as an activity carried out “with people,” not only “for people.” In using a participative approach [21]

that involves the user directly and actively in the design process [22], users utilize design representations [23] as models and prototypes in order to develop the most effective solution.
Using a model or mock-up as a means to create a tangible design proposal has a number of benefits [24] that are relevant to the present project:

- It involves and encourages user participation through manual activity.
- It is easy to understand, and there is no confusion between simulation and objective.
- It allows for varying levels of technical skill, and requires basic materials such as scissors, cardboard and glue.
- It is low-cost, which allows for experimentation.
- It is a fun activity that provides recreation and stress relief.

## 3 METHODOLOGY

The present study uses the DCU workshop objectives as a starting point: it seeks to apply a user-centred design approach to product design, encourage user participation in product design and finally enact strategies for social integration from the standpoint of design.
The project was ultimately a collaborative endeavour, involving the University of Bío-Bío, the Centre for Innovation of TECHO and the community of Nonguén.
A group of professors composed of 2 industrial designers and 1 psychologist designed and coordinated the project. Together with a team from the Centre for Innovation of TECHO (1 industrial designer, 1 industrial engineer and 1 commercial engineer), they presented the project to the community leader in order to make necessary adjustments and coordinate schedules with community members. During the first stage, 12 families signed up to participate. The group of 46 university students thus divided into 12 project groups. The following roles were assigned:
Area coordinator: 1 design professor, 1 member of TECHO, 1 community leader and a student representative.
Design professors from the UCD Workshop (3): Planning and coordination, project follow-up and oversight
Students (46): Leading of the design and planning process with families
TECHO team members (3): Coordination, follow-up, evaluation, and decision-making
Families (12): Definition, evaluation, decision and approval
Project activities were scheduled according to the design program's trimester calendar, and were organized into two areas: 1) main curriculum and 2) core subjects, which provide students with theoretical tools necessary to carry out the project.

*Table 2. Timetable of Design Workshop stages*

| Trimester | **I°** | **II°** | **III°** |
|---|---|---|---|
| Months | March-June | July-September | September-December |
| Course | **Design Workshop** | Core subjects | **Design Workshop** |
| **Stage** | **1,2,3,4, (5-6)** | | **(5-6), 7** |

The trimester academic schedule (Table 2) results in a temporary break in the design workshop, during which students develop technical skills and procedures in core subjects that are relevant and applicable to the third trimester workshop. Core subjects include "Introduction to Design" (Reverse Engineering), "Computational Design II" (product modelling), "Process and Production 1," "Semiotics of Objects" and "Prototypes."
The project was carried out in the following stages:

1. **Invitation**
   The workshop focused on preparing students for project activities, using an explanatory sheet to guide the process. Hosts presented project goals and expected outcomes of the community intervention, highlighting the use of everyday language specific to women homeowners and caretakers (opposed to specialized language), which would facilitate communication and co-construction. Through direct coordination with the community president, a meeting time was set during monthly assemblies in order to invite families to take part in the project. This allowed for a better understanding of the community structure and participation or rate of involvement of residents. Moreover, a list of interested participants was obtained.

2. **Study of the Context**
   Using the list of participants as a guideline, students were divided into groups of 3 to 4 and assigned to a specific family. Each group worked directly with the family in order to coordinate a time for carrying out research and fieldwork (crucial to understanding the local, lived reality of the family). Certain factors were taken into consideration such as family composition, number of children, type of employment, and even disposition, which influenced the family's investment in the project. Some groups met two consecutive days, and others met during brief intervals throughout the day. These meetings allowed students to familiarize themselves with the specific requirements and needs of the family.
3. **Problem Identification**
   The next step was to order, classify and distinguish problems, needs and desires among the many concerns expressed by families to then orient them towards design problems. A participatory approach involving conversation and reflection was utilized. For example, users took part in card-sorting, which allowed them to define, rank and assign value to their needs in response to priority or urgency—and with attention to available resources. Students were then able to make observations using written notes and sketches, as well as identify elements that contributed to the problem. Moreover, students constructed a small-scale model of the problem context.
4. **Conceptual Design**
   Once defined, the objectives included both a proposal and attributes. This was, in essence, a theoretical commitment to both specifying product typology and classifying attributes or characteristics which would provide solutions to the problem at hand. It also served as a guide with which to carry out a formal exploration of the conceptual design—a representation of the general qualities of the proposal.
5. **Development and Co-creation**
   During this stage, the user was invited to simulate the proposal by interacting with scale models of the design. This process highlighted key factors involved in the design process, such as gestures, space limitations and conditions, and the interaction of multiple objects, among others. More than simply encouraging users to participate in co-creation, they were also inspired to modify and adapt proposals using basic materials such as cardboard and clay. In most cases, user interventions were minor, and as a result students were encouraged to also submit a photographic record and notes taken during the session.
6. **Testing and Approval**
   In this stage, a prototype was constructed in order to finalize design details, taking into consideration the availability and affordability of materials in the region. In addition to testing product usability, products were tested to ensure their functionality.
7. **Implementation**
   Each group took part in pre-production, with a total of 2 to 3 units produced per product. Each group delivered a prototype of the final product to their respective families.
8. **Evaluation**
   After 2 weeks, each group met with their respective families to better understand and evaluate in situ the performance of the prototype. In addition, a questionnaire was handed out to families in order to gather feedback on product functionality, usability, disuse and appearance. Two types of solutions were highlighted: autonomous objects, which were more intuitive and easily utilized, and accessory objects, which, when isolated from their context, did not have a simple and independent function, and thus required a counterpart. (Function: achieved by all products on good terms; Disuse: capable of being stored and/or saves space. When the object takes up space, the user values its functionality; Appearance: it is integrated into the home and combines with other objects, considering user tastes. In some cases, appearance was not successful, however, the object did meet basic needs).

## 4 RESULTS

Twelve products were approved by users and moved on to pre-production, with 2 to 3 units produced by each group. In addition, each group delivered one functioning prototype to the family with which they carried out the project. The designs, which responded to a series of problems, took the form of various products, including a clothes dryer (outdoor and indoor), dish-drying rack and toy organizer.

In order to achieve this, both designer and user maintained contact throughout the co-creation process, developing analogous tools (archetypes, drawings, models and prototypes) that facilitated dialogue and, as low-cost and low-tech solutions, made for a more informal and relaxed creative endeavour.

## 5 CONCLUSIONS

Experiences from the activity provided important lessons, particularly on two fronts:
Educational: Visualizing and valuing new design opportunities for a different market segment; Developing low-cost and practical design solutions with materials and processes that are specific to local contexts; Learning to open up a space of dialogue and communication regarding design ideas proposed by users in non-academic contexts; Learning to work with others, taking into consideration and accepting differences in order to deliver a product that responds directly to user needs.
Personal: Strengthening social interaction, specifically with people living in other social contexts, providing a more comprehensive look at the lived realities of residents, and thus developing crucial social skills such as empathy and respect, which help to establish and build trust—both key for developing and sustaining collaborative projects.

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# A WORKING MODEL TO INCREASE AWARENESS OF SOCIAL IMPACT

**Jantine BOUMA**
Human Technology, Institute for Engineering, Hanze University of Applied Science, The Netherlands

**ABSTRACT**
Designers are not always aware of all social consequences of technology, despite practicing user-centred research. With the introduction of disruptive technologies intended and unintended social impacts can be expected, therefore they need to be anticipated. But in general design practices social impacts are completely overlooked. An awareness of the need to anticipate social impacts will not develop automatically. For this purpose a model of awareness has been developed. The model has been evaluated by 12 students. It appeared that the students were able to use the working model, but it turned out to be difficult to imagine changing social practices. It was therefore concluded that students need to increase understanding of the complexity of social practices.

*Keywords: Social impact, model of awareness, anticipation, technology*

## 1 INTRODUCTION
The use of email communication, mobile phones and cars are examples of technologies that have had wide-ranging social consequences. Email, for instance, was developed as an efficient mode of communication between two actors. As we all know, the introduction of email has fundamentally changed traditional business and office practices. These side effects were not identified until long after email was introduced.
During recent years, designers have grown increasingly interested in social impact of new technologies. Modern information technology, in particular, creates extensive possibilities to influence social behaviour. Persuasive technology has been developed to increase, e.g., environmental friendliness. Once a designer aims at defined social changes, the consequences of technology for practices become a responsibility, too. This may have consequences for design education.

### 1.1 Social consequences of technology: mediation
The process leading to changed social practices is called mediation. Mediation comes about in a complex interplay between technologies and their users [1]. The consequences of these mediations on social interactions will be referred to as social impact. According to Verbeek [1]'Technologies enable us to perform actions and have experiences that were scarcely possible before, thereby helping to shape how we act and experience things.' Technology, therefore, is active: it helps to create a situation that was not possible without technology. A new technology is changing the script [2] of its users. This mediation between users and artefacts is formed by interactions.
A new technology will be translated into a form that is more appropriate for potential adopters, by choosing some elements of the technology and leaving out others [3]. So, it is not sure what kind of mediations will take place. The potential adopter will not use all scripts available. A social environment will have an influence of its own [4]. This means that social impacts are difficult to predict at forehand.

### 1.2 Importance for designers
If unintended consequences can be expected it may be wise to avoid them in social contexts. This seems, however, to be a poor solution. According to Christensen, Bohmer and Kenagy [5] disruptive technologies may be the cure for healthcare, because the healthcare needs to be transformed. Managers and technologies need to focus on getting less expensive professionals to do more sophisticated things

(with the help of technologies) in less expensive settings. It is needed to design disruptive technologies and therefore it is needed to perform anticipations of social impacts.

In order to anticipate the future use of a product an engineer needs to have an understanding of the working of the technology in the real world, which Roozenburg and Eekels [6] refer to as the cosmonomy. This reality is simplified through causal models. Insights from causal models are translated into concepts, which can then be tested in the real world.

Insights into social impacts need to be translated into concepts for new designs. These steps can also be applied in anticipations of social impact [7], but, unlike technical impacts, social impacts are completely overlooked in design contexts. A probable cause for this is that mechanical engineers are confronted with unintentional consequences of products immediately. Malfunctions within a product can lead to high costs and user dissatisfaction. In the case of social impact, however, consequences are not directly related to a new technology and may evolve over time. A designer is not directly confronted with unwanted social impacts. An awareness of the need to anticipate social impacts will not develop automatically. It is therefore important that a designer is able to assess whether implementing the anticipation of social impact in a design process is necessary or not. This has implications for design education. Future students need to become aware of the risks of social impacts when designing for sociable sustainable solutions.

### 1.3 Awareness of social impact

It is needed to assess whether technology will lead to social impact. Disruptive technologies in design environments are already viewed from the perspective of whether they are able to change social contexts. An example is the introduction of the compact disc player and, more recently, the iPod [8]. A difference is that these visions of disruptiveness focus on the question of what kind of innovation is needed to make sure that a company stays healthy. Only focusing for instance on incremental innovations is considered to be a risky strategy that might harm a company in the long run. This explains why a matrix to describe disruptiveness is called the 'Ways to Grow' matrix [9]. The matrix evaluates innovation efforts within an organization. This model focuses on what a company needs to know in order to design a new product (new offering) for new users. However, it does not explain the consequences for the social environment itself. What social practices will be changed through new technology?

According to the paradigm of social impact, the disruptiveness of designs will be considered from the perspective of outcomes. When technology intervenes in a script, leading to changed practices, a technology will be considered disruptive. Thus observed, innovation might be understood differently[1]:

- A new technology (new offering) means that the kind of social impact that can be expected is unknown. It might be difficult to know which contextual characteristics will lead to what kind of social impacts; unintended outcomes may therefore be expected [3].
- Users are replaced by social practices: understanding a new social practice leads to difficulty in understanding the consequences of implementing a new product, because social patterns are not identified. Hence, there may be a higher risk of unintended outcomes.
- Another aspect that can be disruptive for a social environment is the question of whether a certain practice is about to be changed through a new technology. A product designed to interfere with a script might lead to changes in social interactions and can therefore be considered disruptive.
- Vulnerable users may have fewer options to adapt their behaviour to changed practices and are therefore more affected by the introduction of new products[10].
- When a product is developed for an undetermined social environment, it is much more difficult to control and anticipate social impacts of a new product and hence the consequences can be more disruptive.
- Finally, a product that mainly has individual consequences is believed to be less disruptive than a product which has social consequences as well.

A designer therefore needs to understand different aspects of disruptiveness in order to understand the possibility of social impact. From this analysis six dimensions can be defined which are translated into three matrixes:

1. The newness of the functionality of a product **vs** the newness of the social practice; this explains the expected difficulty of an innovation.

[1] For an explanation of how these aspects have been deduced from literature and earlier studies, see [7]

2. The way practices will be influenced **vs** the vulnerability of the expected users; this explains the expected level of social impact.
3. The expected environment in which the product will be introduced **vs** the expected individual or social consequences; this explains the expected scope of influence.

## 1.4 A working model

In this section I will discuss the six dimensions of the working model.

### 1.4.1 Matrix 1: expected difficulty of innovation (figure 1)

This matrix is linked to the ‘ways to grow matrix’ and aims to determine the level of innovation of a new technology. Introducing new functionalities in unknown social contexts causes uncertainty about the consequences. This makes it more difficult to anticipate social consequences.

Existing vs new functionality: A user is only influenced by new technology if it offers new functionalities. A new functionality can be a new technology (for instance, nanotechnology), but can also be an existing functionality that had hitherto been unavailable to a user. The social impact of cars was felt only after users acquired cars.

Known versus unknown social practices: practices consist of interaction patterns within social environments - such as the interactions between members of a social environment within a physical and technical context. An example would be the members of a family or workers in an office. It is easier to develop a product for a well-known practice than for an unknown practice.

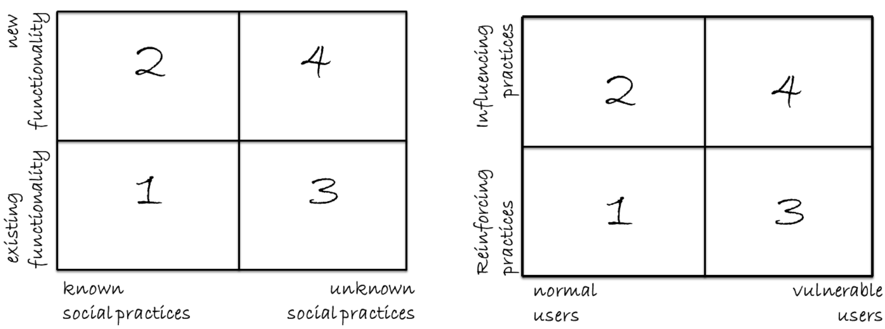


*Figure 1 and 2. the expected difficultness of innovation and the expected level of social impact*

### 1.4.2 Matrix 2: Expected level of social impact (figure 2)

This matrix determines the ethical responsibility and necessity to anticipate social impact.

Reinforcing or influencing existing practices: A designer needs to consider what the starting point of a new design is and what his intentions are. Is it his intention to influence or merely to reinforce existing practices?

Normal versus vulnerable users: Whether a user is vulnerable depends on the technology that is introduced. A change in our energy supply requiring us to use less energy and forcing us to use the washing machine at night can be inconvenient. But it is questionable as to whether such a change will lead to harmful situations. However, when a hospital introduces a new care system for nurses, the relevant patients are vulnerable to changes, especially if they are unwanted and unexpected.

### 1.4.3 Matrix 3: Expected scope of influence (figure 3)

This matrix determines the scope of influence of the anticipated social impacts.

Specific versus general environment: Is it possible to determine what kind of users will be using a product, and in what kind of physical and social setting? In that case, social impact can be determined for a specific environment. If it is impossible to specify a social environment, we refer to a general social environment.

Individual consequences versus social consequences: This attribute is related to the possible consequences of an anticipated product. Is it restricted to individual users or does it also involve social environments? A digital whiteboard is focused on the use in a social environment, while a shaver is focused on individual use.

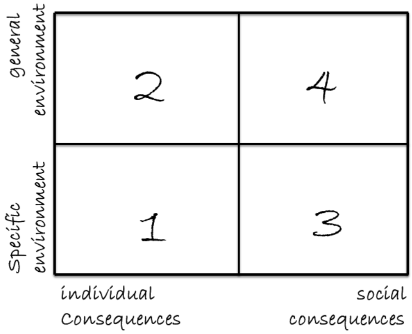


*Figure 3. expected scope of influence on ….*

The model of awareness does not give absolute, quantified results. The model is meant to stimulate discussion between designers and to stimulate the anticipation of social impacts in design contexts. In a next stage of research, it is important to verify whether the model has the ability to generate new discussions between students. The goal of this research is an evaluation of the model of awareness in educational settings.

## 2 EVALUATION OF THE AWARENESS WORKING MODEL

A descriptive study was carried out to evaluate the working model. Students doing a Care and Technology minor at the Hanze University of Applied Sciences were selected for this purpose. Twelve students from different academic backgrounds (social, medical and technical) completed the questionnaire; 3 female and 9 male.

The respondents were presented with two cases and asked to decide how much social impact the products in these cases were likely to cause. The first case involved a urine analyzer intended for use in a hospital for patients in the intensive care. In the current situation, urine is collected and taken to a lab. In the new situation using the new analyzer, urine could be analyzed directly at the bedside.

The second case involved a homecare system developed by Nedap, a manufacturer of intelligent technological solutions. Nedap proposed to redesign its homecare system in order to make this suitable for hospital use. The products have not been developed at this moment. The respondents were asked to make a preliminary assessment anticipating the social impact of the products and needed to use the working model to help them to become aware of possible impacts.

In the questionnaire, the respondents were asked to rate each dimension on a scale from 1 to 4. Furthermore, they were asked to explain why they had chosen a particular score. The respondents' explanations were categorized according to their relation with the question asked (green: in line with dimension, yellow: more or less in line, red: not in line with dimension). The answers were only used to see whether respondents were able to justify their answers based on the given dimensions.

### 2.1 Results

The results are represented by case and matrix.

### *Results for matrix 1: expected difficulty of innovation*

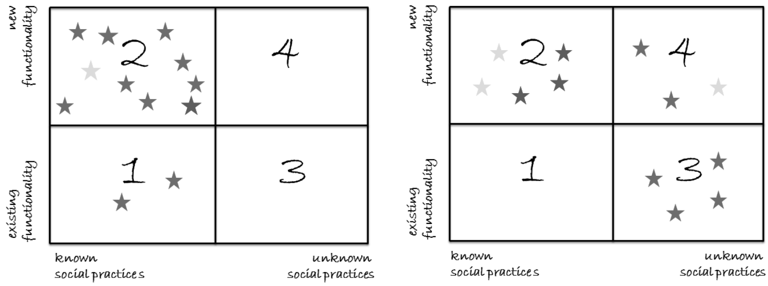


*Figure 4 and 5. results for case A and B of the expected difficultness of innovation*

Case A Urine analyzer (figure 4): The respondents agreed on the fact that the product would be introduced in a known environment. Whether the functionality was new or already existed remained a point of discussion, although the majority agreed that it was new.
Case B Planning system for a hospital (figure 5): The opinions about the difficultness of innovation of the respondents were more varied and there were more answers that were not related to the matrix ‘difficulty of innovation’. For instance, the five respondents who chose option 2, all gave motivations that were not in line with the dimensions.

### *Results for matrix 2: expected level of social impact*

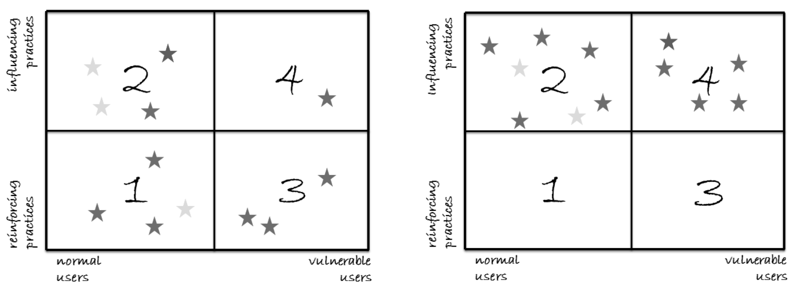


*Figure 6 and 7. results for case A and B on the expected level of social impact*

Case A Urine analyzer (figure 6):The expected level of social impact is viewed differently by the respondents. Most respondents considered the target group to be the patients’ physicians, others focused on the patients. One respondent thought that practices were influenced for vulnerable users.
Case B Planning system for a hospital (figure 7): For this case the expected level of social impact is viewed more equally. The respondents agreed that the product would influence hospital practices. They differed on who the target group of the product was; normal users or vulnerable users.

### *Results for matrix 3: Expected scope of influence*

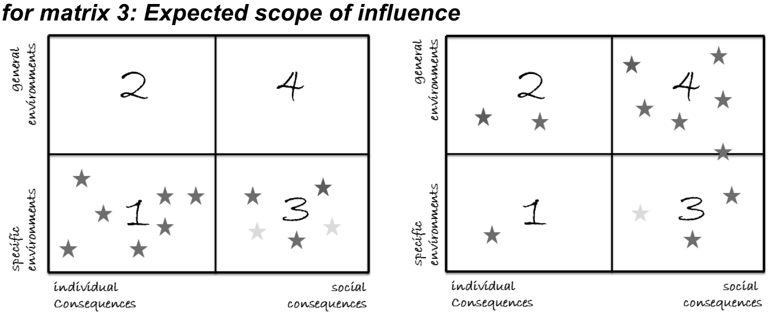


*Figure 8 and 9. Results for case A and B on expected scope of influence*

Case A Urine analyzer (figure 8): The respondents agreed that the use of the urine analyzer occurs in a specified social environment. What they did not agree on is whether the product influenced individual behaviour or individual and social behaviour.
Case B Planning system for hospitals (figure 9): The respondents showed greater variation in their answers regarding the scope of influence of case B. Most arguments were in line with the dimension; the estimated use of the product was interpreted differently.

## 3 DISCUSSION AND CONCLUSION

This study was carried out to determine whether students were capable of using the model of awareness. Although some respondents used unrelated answers in some cases, most answers were related to a matrix. The model would therefore appear to be able to be understood by most respondents. Where the respondents appeared to be less clear about a case itself, their own interpretations increased. For instance, the respondents seemed to find it hard to interpret the social impact of the urine analyzer, which led to more unrelated answers being given, but for the planning system for hospitals it seemed to be less difficult to give answers that related to the different dimensions.
In general, it was found that respondents have difficulties in understanding the complexity of a social practice. An example of this is the fact that most respondents thought that specialists would be the sole users of a urine analyzer (case A) in a hospital, in the case of the new planning system for nurses (case B), that only nurses would be involved and that these products would have no impact on patients. My assumptions had been that these would be clear examples of vulnerable users.
For this target group, it may be necessary to increase understanding of the complexity of social environments. This might lead to a better understanding of the influences involved in the cases.

### 3.1 Conclusion

Students need to gain more knowledge about social practices in order to be able to use the awareness model properly. The model of awareness therefore will be extended with an analysis of the social practices involved at forehand. The use of a screenplay method [7] that allows simulating new social practices might be beneficiary.

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# AN INTEGRATED SOCIAL INTERACTIVE TOOL TO IMPROVE KNOWLEDGE SHARING AMONG STUDENTS

**Way Kiat BONG, Xiangyang YANG, Yang YANG, Anqi ZHAO and Weiqin CHEN**
Department of Computer Science, Faculty of Technology, Art and Science, Oslo and Akershus University College of Applied Sciences, Oslo, Norway

**ABSTRACT**
Knowledge sharing is important to students in their learning process. However, students come from different background and cultures, speak different languages and work or study in different ways. They need to use many websites or tools to achieve the aim of their knowledge sharing. All these are problematic and time-consuming to students. Therefore, an integrated tool would be preferable to overcome these issues and thus, promote knowledge sharing between them. This paper presents the literature review, survey and interview on which the design of an integrated knowledge sharing tool, Mybook, was based as well as the user testing of Mybook with students.

*Keywords: Social interactive tool, knowledge sharing*

## 1 INTRODUCTION

Knowledge sharing is undeniably important. While students learn, they share and exchange academic information with one another. In fact, what being shared is not only academic information, but also practical information such as venue, time table and news about the courses. Thus, knowledge is shared in the form as information flow between students and teachers and among students themselves [1]. Paulin and Suneson [2] defined knowledge sharing as the exchange of knowledge between and among individuals. They stated that the focus of knowledge sharing is on human capital and the interaction of individuals in knowledge sharing. Since knowledge sharing involves interaction of individuals, social interactive websites such as Facebook can be a good platform for this purpose. Social sites like Facebook is more universal applicable than other websites as it serves people from different countries.

Students and teachers use different communication systems and different ways of working as compared to one another. One might use email to communicate while another prefers to use instant messaging. One teacher might post information in Learning Management Systems (LMS) such as Fronter, Moodle, and Blackboard; while others might like to inform via email. These tools can be categorized into two levels: tools for specific purposes such as email, instant messaging and integrated tools such as LMS and forum sites. Therefore, students find it burdensome when there are many different systems for their daily educational purposes. Besides, due to the different background and cognitive ability, language and graphical layout become essential factors in the usability of applications or websites. All these websites or systems serving different purposes with different layout make it difficult and time-consuming to students. Particularly it is difficult for international students to use systems or websites that are only in local languages. For example, announcements published in Fronter, a widely used LMS website in Norway, become troublesome to international students as some of the pages are written in Norwegian and are not automatically translated to English even though the language set by the students is already English.

Nevertheless, students are also required to use different websites to achieve their educational related tasks. For example, getting course resources in Fronter, checking venue at WebUntis, getting exam result in StudentWeb, sharing documents in DropBox or Google Document, and discussing group project on Facebook. This add extra burden to the students as they need to remember more passwords, user names and so on. Thus, this research aims to make knowledge sharing easier by proposing an integrated social interactive tool, which combines several websites or functions that students use in order to save students' efforts and time.

This paper is organized as follows. Section 2 introduces the literature review about related works to knowledge sharing. Section 3 and 4 present findings of the survey conducted with 91 students in Norway and interviews with six international students to identify the requirements for the proposed prototype. Section 5 introduces the prototype designed based on the findings from both surveys and interviews. Section 6 presents the results of user testing. Finally, Section 7 concludes the paper with discussions of the limitations and future work.

## 2 LITERATURE REVIEW

According to McInerney [3], knowledge can be acquired through reading and listening to others. If this is so, then one important conduit for knowledge sharing among individuals in online environments is online conversation [4]. Nowadays, conversation occurs online in the form of instant messaging, e-mail and online discussion forums. Sharratt and Usoro [4] suggested that within the context of online environments, the direct mechanism for engaging another member who may possess the required knowledge is to post an open question or a request for help to the online network or community. Therefore, it is actually more efficient and effective to have a common platform where students can ask and answer, and most importantly the common platform has to be actively used and not felt as troublesome by the students.

In addition, Wasko, Faraj and Teigland [5] found that high participation (including sharing knowledge) in an electronic network was due to the easiness provided by technology. It only demotivates the students to participate actively if they are required to make extra efforts (i.e., going to different websites to retrieve related information). Students would prefer one technology integrated of all that they need to use in their educational tasks.

Resource sharing includes sharing documents, links, videos or images. Educational recourse sharing provides a platform for teachers and students to share the knowledge and at the same time to compile them. The resources are in public sharing networks, databases and can also be derived from the individual on the network share. The databases of educational recourses sharing are divided into many different discipline databases such as telecommunication engineering recourse database and higher mathematics recourse database. It is easier for users to search knowledge. Recourses sharing makes dissemination of knowledge more efficient and effective and that is definitely required in an integrated social interactive tool for educational purpose [6].

Search engine enhances learning flexibility and adaptation, promote knowledge creation, share, capture and shorten the knowledge acquisition time [7]. Apart from this, Kim and Tse [8] points out when the search engine should introduce a knowledge-sharing service rather than to increase its search quality for more profits. In accordance to that, an integrated social interactive tool with search engine can provide better knowledge sharing platform.

Document storage is no longer a problem nowadays due to its commonality. In healthcare, research has been conducted on the foundation for collection of health data, which was related to maintaining the privacy and security of sensitive information [9]. However, very few studies have focused on how to make document storage better in education context. Hence, it is important to find out if students would like to have document storage integrated into a social interactive tool when it comes to the sensitivity of information.

## 3 SURVEY

A survey was conducted to understand how students share knowledge and use the required or available technology to perform their educational tasks. Understanding the situation would provide a foundation for improving the current solutions. There were a total of 10 questions in the survey and 91 respondents from Europe (76.92%), Asia (17.58%), Africa (3.30%), Americas (1.10%) and Oceania (1.10%). The results showed that 90 out of 91 students do use social interactive tools or websites such as Facebook and 72 out of 90 of them actually use them every day. 81 also use them for educational purpose, such as discussion, learning, group assignment, etc.

Other questions included the usage of several educational related websites. For instance Fronter, Dropbox for online storage, Google Document and library search engine. More than 50% of the respondents use them often in their educational activities. Lastly, they were asked if an integrated social interactive tool which combines their daily used educational websites or tools would help their lives as students. The results were rather positive, with 60 out of 91 saying yes. All in all, this survey supported the proposed idea of an integrated social interactive tool for educational purpose.

## 4 INTERVIEWS

Six international students from Oslo who use Fronter regularly were interviewed to gain deeper information regarding to the requirements of the social interactive tool [10]. First of all, they were positive about integrating several educational websites that they use so that they do not have to visit many different websites and remember their user names and passwords. For their educational activities, they mentioned that they do use Facebook for communications and discussion, while Dropbox is often used for document sharing and storage. Features that pointed out by them were sharing documents, chatting and discussion. Both Facebook and Dropbox were essential applications for their knowledge sharing.

Fronter was where they visit often to get course materials and announcement from the lecturers and school. Besides, they also needed to access WebUntis to check on venue of the classes sometimes. Thus, it is more apparent that an integrated tool will ease their lives.

The participants in the interview also suggested integrating student email and discussion or chatting tool to ease their communications with others. *"It was troublesome for me to check my student email because I do not know when there is incoming unread email in inbox. I have to check in Fronter from time to time"*, said one of the interviewees. Hence, it will be more convenient for the students to have them integrated rather than accessing different websites to check on related matters.

Furthermore, they also voiced out their difficulties with searching room, news, announcement, materials and so on in Fronter. There is no search function in Fronter as of today. They felt frustrated because they had to use try and error method to find what they wanted. Most of them agreed that Fronter website that they were using daily had severe design flaws in layout and navigation flow. One of them said *"Fronter needs too much clicks. I do not know where to find the information sometimes."* Example given (Figure 1) was when they needed to access the 'room' (subject/course) in Fronter. After opening one room and wanting to open another room, user is always required to click 'Rooms' and 'Display all rooms' again even though this has been done previously while opening the first room. The interviewees commented that this step was not necessary as it is repetitive. This process was commented as not user friendly either because novice users might not know where to click at first. Most of them had this problem when they started using Fronter.

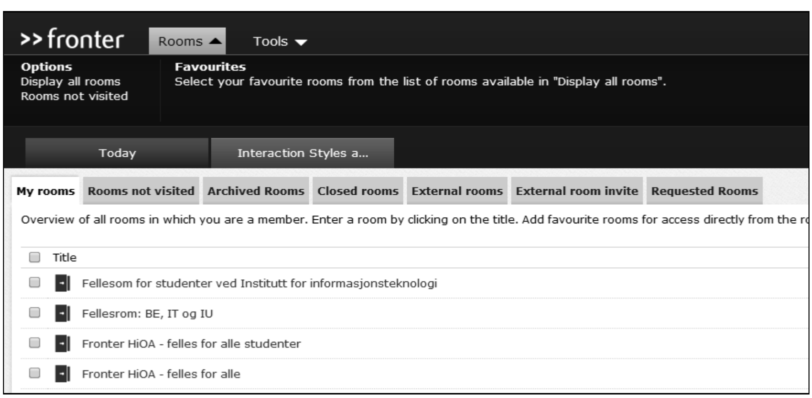


*Figure 1. Fronter 'room' page*

Furthermore, setting the default language as English in Fronter does not help translating the announcement made in Norwegian (Figure 2). For international students, this is a frustrating issue because they have to find their own ways to translate the announcement.

Overall, the issues identified in the interview have been addressed in the prototype which is presented in the next section.


*Figure 2. Fronter 'language' problem*

## 5 PROTOTYPE

Based on the survey, interview and literature review, the prototype is designed to integrate the following components, which are (1) discussion or announcement, (2) document storage, (3) document sharing and (4) search engine. A user-centered design approach has been adopted to ensure issues faced by users are resolved. A low fidelity prototype has been developed based on social site Facebook and named as Mybook, which is an integrated social site for students' social and studies activities (Figure 3).

The integrated site aimed to resolve students' problem of visiting multiple websites and having to remember multiple user names and passwords. The reason for using Facebook as a referral prototype was that it is widely used in most of the countries and therefore, students from different countries will probably find the layout most familiar and user-friendly. The prototype was designed to integrate four main features, which are discussion or announcement, document storage, document sharing and search engine; and at the same time, suggestions from the interviewees have been taken into consideration.


*Figure 3. Prototype "Mybook"*

The left hand side of Mybook has two main components namely 'Social' and 'Study'. Under 'Study', students can find the homepage where public announcements from the school are posted. Next is the student email. There are also courses that student are enrolled in. After clicking at course name, there will be tabs where they can find announcement or discussion area, members, resources for document storage and sharing, and hand-in section. Figure 3 shows the announcement about someone uploaded a document and a change of venue at tab course "Master's thesis".

By using the tab "members", the students are expected to find their classmates and lecturer easily. Tab "resources" is where students can access to materials for the course. Last tab "Hand-in" is where students submit their assignments, projects, etc.

The design of Mybook was to minimize the number of clicks that students have to perform to reach each function in order to increase task efficiency and effectiveness. Using Fronter to access different "course" room will require three but using Mybook it only require one click. In addition, the layout is also much easier to be navigated because the courses are all listed in one page, which does not require students to navigate from one page to another in order to search for the courses.

For search engine function, there is ‘Library’ which links directly to school library databases. Besides, there is a search box in the top bar where students can search for related information, just the same as in Facebook. Lastly, the prototype also keeps the original function as Facebook at the right, which is chatting tool with friends or groups, as suggested by interview participants. This is to ease individual or group discussion.

## 6 USER TESTING

User testing was conducted with five international students who are currently studying in Oslo [10]. The goal of the testing was to see if the students found it easier and more satisfied using Mybook, an integrated social interactive tool for their studies. Each testing took less than 30 minutes and both qualitative and quantitative data were collected. A Likert scale questionnaire was given to the participants at the end of the user testing for quantitative data while observations were done for qualitative data. Participants were free to provide feedbacks on the prototype after the testing.

The testing tasks were to identify where to (1) access the page for a course, (2) submit assignment, (3) find classmates from the course, (4) send email, (5) search resources for library, (6) chat with other students, (7) find other shared documents, and (8) get updates from social news feed. All five participants managed to complete most tasks in less than five seconds. They scored mostly ‘agree’ and ‘strongly agree’ when they were asked about the easiness to perform testing tasks. This clearly indicated that the layout of Mybook is easy to use. The students were also familiar with the layout of Mybook due to their familiarity of Facebook. One of them said, *“This looks just like Facebook! So it is easy for me to use”*.

All five participants also found it much simpler using Mybook. By using Mybook they did not have to click as much as using Fronter and the main contents were all shown in first page rather than hidden as drop down pane and required click to have them shown up. Using Fronter to access a course room will require three clicks each time and this process needed to be repeated for every single course room. In Mybook, all the course rooms are displayed at the left as a list. Therefore only one click is required for accessing any course room. This list, however, has its drawback when there are many courses enrolled by a student. The average amount of 4-6 courses was taken into account while designing the display as a list.

All five participants felt more motivated to check educational information since it is much convenient to have all educational information integrated into one website. At the same time, they also felt much easier with remembering fewer user names, passwords and even websites. Lastly, they agreed that integrated website could promote knowledge sharing.

All in all, all of the participants were satisfied with using Mybook. The only negative feedback was one of them disagreed with that “it is easy to find document sharing/storage made in the website” due to confusion of the term “resources” and “document sharing”. Some suggestions were given, including file sharing directly at chat function, separating or grouping friends into different types such as social friends, classmates, and changing the name “resources” to “document sharing” and “hand in” to “upload”. One participant mentioned that combining study with social activities might cause distraction. This could be further studied with more students in the future.

## 7 CONCLUSION AND FUTURE WORK

This paper presents the research on investigation of problems with current knowledge sharing tools and the design of prototype Mybook. The investigation used survey and interview for data collection. The results guided the design of the Mybook which was then evaluated by five students. We received positive feedback about Mybook as an integrated social tool for knowledge sharing in the context of education. The findings from the user testing indicate that Mybook provides an easy-to-use technology for students to communicate online [4], share resources [6], participate in joint activities [5] and knowledge creation [7] efficiently.

Mybook was designed based on the students’ interview results on Fronter only. Therefore, further research is necessary to study other LMS in order to generalize the results and identify other issues. Moreover, this study focuses mainly on students. There are also other stakeholders such as faculty members, administrators, who shall be included in the user-centred design process. Expanding the scope to include other LMS and stakeholders would improve the design of higher fidelity prototypes of Mybook.

Another limitation of the study is the lack of high fidelity prototype with complete functions. This limited the participants from conducting the tasks in depth. Hence it is difficult to tell if Mybook can really work well. With high fidelity prototype, perhaps more students can be invited for user testing as well to gain more insights into the usability of the prototype.

The combination of students' social activities and studies is very subjective as different students might have different perspective. As shown in the user testing, one participant was not convinced that combining both of them could actually motivate her to participate more actively in her studies. Hence, future work in the high fidelity prototype can also include having the option to disable social part of the website, if it is preferred by students. Students can then choose to have 'social' disabled while they do not want any interference from 'social'.

The testing result and questionnaire answers might be biased by students favoring the score for prototype. Therefore, it is recommended to have future testing which focuses on comparative tasks between existing method and the prototype in order to show if prototype is really more effective and efficient. Another problem that was highlighted, auto-translating language, shall be looked into in future work as well. Facebook, as the reference of the prototype does not auto-translate the posts made in other language into defaulted setting language.

The current low fidelity prototype is only sufficient to resolve problems of using multiple websites or tools and the graphical layout issue faced by students. Future work should focus on developing high fidelity prototype where more in depth user testing can be conducted with more actual tasks. All in all, Mybook as an integrated social interactive tool has the potential to promote the knowledge sharing among students or even with lecturers in the future.

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# "SHOULD I PATENT THIS"?

**Bryan HOWELL**
Brigham Young University

**ABSTRACT**
This paper addresses the recent legal and cultural evolutions within the United States Intellectual Property system and its impact on Industrial Design students. It reviews how the United States Congress has revised patent laws, diluting the rights of the inventor in favour of the inventor's sponsor. It also explains cultural shifts in patent creation and ownership, with teams of inter-disciplinary inventors employed by well-funded corporations at the core of the patent world. It then highlights how these changes do not favour student inventors and hinder their ability to protect their creative work.
This paper also explores how recent patent language includes claims of "user experience" and "usability" which can benefit industrial designers. It highlights intellectual property issues that students encounter, namely, dealing with creative rights ownership and Intellectual Property education. Finally, it proposes how design students and universities could evolve their traditional positions regarding intellectual property and their education methods to align training with the new intellectual property realities in the United States.

*Keywords: Intellectual Property, design student, usability, user experience, technology transfer*

## 1 INTRODUCTION

Recently our Industrial Design (ID) department witnessed an unfortunate argument between students over perceived intellectual property rights. Both sides engaged attorneys to argue their positions. Soon thereafter, the argument silently dissipated with no action taken by either side. The details regarding this conclusion are unknown, but it is suspected that neither party held "rights" that were legally pursuable and thus all arguments were mute. Unfortunately, it took two attorneys to clarify the situation to the young designers who were at the time passionately absorbed by the situation.
Industrial Design students create unique solutions to academic projects and often ask themselves (and their professors) "should I patent this"? Typically students hold an idyllic view of patents and their rights as a designer. They envision themselves as inventors akin to Thomas Edison, the Wright Brothers, and "Doc" Brown from the movie Back to the Future, who sacrifice countless hours and social relationships to develop products that will change the world and potentially create a substantial financial return. However, this notion of a "lone genius inventor" is "antiquated" and is partially to blame for conflicts similar to that mentioned above.
Over the last few years the intellectual property scheme in the United States has evolved and design students should understand the basics of patent law and trends so they may efficiently use limited resources wisely. These transformations include both legal and cultural changes. First, the United States Congress has altered patent laws, diluting the rights of the inventor in favour of the inventor's sponsor. Second, cultural shifts in patent creation and ownership place teams of cross-discipline inventors employed by large well-funded corporations at the core of the patent world. These changes do not favour the student inventor and significantly hinder their ability to protect their creative work.
However, there are emerging trends working in favour of industrial designers and potentially, student designers. These include the acceptance of "usability" as a driving force in patent "claim" language, and a push to license intellectual property developed in American Universities. Also, Industrial Design students should understand how these evolutions might affect their educational and private lives. Furthermore, the academic design studio, working on sponsored projects, is an ideal vehicle for learning about intellectual property issues.

This paper addresses the recent legal and cultural evolutions in patent law and proposes how design students and universities could evolve their traditional attitudes towards intellectual property and alter their education methods to align with the new intellectual property realities in the United States.

## 2 THE INDIVIDUAL INVENTOR

On June 1st 2011 the United States Committee on the Judiciary submitted to the US House of Representatives the America Invents Act to amend portions of Title 35, of the United States Patent Code. In this document, the committee reports that:

> "The U.S. Patent system, when first adopted in 1790, contemplated that individual inventors would file their own patent applications... It has become increasingly common for patent applications to be assigned to corporate entities, most commonly the employer of the inventor... Current law still reflects the antiquated notion that it is the inventor who files the application, not the company-assignee" [1].

The report further states that Section 115 and 118 of the Code should be modified, allowing the obligated "assignee's (corporate entities) to file a patent application" *without* the inventors immediate signature [1]. Historically, this signature has been a precious part of every invention indicating that the inventor has signed an oath "stating that the inventor believes he or she is the true inventor of the invention claimed" [1]. This new power enabling the transfer of inventorship from the inventor to the sponsor with or without the actual inventor's signature is a radical degradation of traditional inventors rights and signals the unimportance of the individual inventor in current patent law.

This brings into question that relationship between student designers and sponsoring institutions. A recent review of the author's institutional intellectual property policy indicates that students own the rights to their creative works. This policy dated October of 2000 states: "Students who independently develop intellectual property arising out of their participation in programs of study at the university will retain the ownership rights to such property" [2]. In this new environment, this statement seems outdated and begs the question, could a sponsoring academic entity transfer student rights to itself, just as a corporation could, without the consent of the inventor?

Typically Industrial Design programs incorporate outside corporations as sponsors for semester long studio projects. These corporations also typically request the intellectual rights to the student's work. Student designers are now in a unique situation. As the individual developers of intellectual property, they have to compete with two different possible sponsors, the University as the sponsor of their education, and the corporation sponsoring the semester's project. Ownership for the intellectual rights resulting from these academic projects could potentially become a three-way struggle between the student, the university and the corporate sponsor.

## 3 FROM INDIVIDUAL INVENTOR TO TEAM INVENTORS

Over that last few decades there has been a significant shift in the "culture" of invention. Corporate inventor teams have replaced the role of the individual inventor. This movement away from individual inventors is corroborated by observations from Dennis Crouch [3] who reports that of the patents filed in the US in "1952, 82% listed one inventor, 15% two inventors and 3% more than three inventors". "By 2011, the statistics had inverted. Less than 32% of patents issued list a single inventor", 25% list 2 inventors and "43% identify three of more inventors".

In a more recent report, Crouch [4] states that the trend showing an increase of patents filed with "teams of inventors" is increasing while patents filed with only one inventor continues to fall". Corporate inventor teams are the natural result of both the cost and complexity of contemporary inventions and the team based development methods that corporation's embrace today.

Most Industrial Design programs train students with simple, non-complex projects with some participation in single discipline team-based work, however, at the end of the semester, it is still the individual designer that is graded, not a team of inventors. Although students occasionally engage in cross-disciplinary projects in Industrial Design programs, it is not yet a standard practice. Consequently, industrial design students are primarily reliant on their individual genius to create patentable features while the trend for new invention is based on cross-disciplinary teams. While it is possible that a student design might invent something that is patentable, it is not probable.

## 4 INDIVIDUAL OWNERSHIP TO CORORATE OWNERSHIP

These corporate inventor teams are performing better today than at any time in history and corporations are using this trend to aggressively increase the size and quality of their patent portfolios. An analysis of patent ownership illustrates that individual inventors, who own intellectual property rights, are, like the individual inventors themselves, being replaced by corporations.

Evidence of corporate patent performance can be found in the IFI Claims Top 50 US Patents Granted list [5], published each year. This shows that in 2013, two popular consumer electronic companies, Apple Computer and Samsung Electronics, were granted a total of 1775 and 4676 patents respectively. Or, in a different perspective they were issued respectively 6 and 16 patents per workday. The process to develop and process patents in corporations is a complex and well-tuned effort. The inventors in those corporations need only get their creation into the hands of a team of attorney's who will nurture it through the patent application and granting process.

Evidence demonstrating that corporations dominate intellectual property ownership is found in the All Technologies Report, PARTS A1 [6] from the United States Patent and Trademark Office (USPTO). It shows that 82.5% of the total patents granted in 1999 where awarded to large entities, including both corporate and government entities. Thirteen years later, in 2012, 93% of all patents granted where awarded to corporations and governments. The relative number of patents granted to governments has stayed relatively flat over these 13 years, thus the growth has been in the corporate sector.

The drive to invent is a critical part of the race to rapidly build the size of the corporate patent portfolio. In today's world of litigation, the size and quality of your patent portfolio is worth millions or as recently demonstrated with the Apple and Samsung court case, billions of dollars. The process to obtain and protect a patent is not trivial, and individual inventors and especially design students rarely have the knowledge, time or resources to effectively protect patent worthy creations.

The patent game today is primarily a corporate game, the idea of an individual inventor or student creating a patent that is meaningful and defendable is an "antiquated" notion and students should be aware of the contemporary realities of the intellectual property world, before engaging in patent fantasy's or litigious argumentation.

## 5 USER EXPERIENCE AND USABILITY

User Experience (UX) is a relatively new term developed and promoted in the Human Computer Interaction (HCI) community. It is has not yet coalesced into a single definition but Law [7] "recommend(s) the term user experience to be scoped to products, systems, services, and objects that a person interacts with through a user interface." Bargas-Aliva [8] also highlights that key dimensions of UX studies include emotions and affect, enjoyment, and aesthetics.

Usability (UI) is a more common term used in HCI studies and is considered a subset of the User Experience focusing on the objective performance of a user interacting with a task, tool and the environment [9]. UX and UI were typically software focused, but are now considered a basic need in most serious new product development.

To stay abreast of the ever-evolving world of product design and development, Industrial Design departments are beginning to include usability and user experience studies in their curriculum. The foundational processes and ideals behind the new UX and UI methods are also useful in increasing the value and performance of non-software inclusive products covered in ID curriculum. With the advent of UX and UI ideals in product development, both in corporations and university curriculum, it will be insightful to uncover if it has influenced patent creation, and if so, then, how?

## 6 UX/UI IN PATENTS

To explore this notion, 10 patents from a single field of endeavour spanning 33 years were analyzed to discover how UI influenced the patents claims. Patents involving Illuminated Keyboards were randomly selected with a simple chronological spacing allowing for samples to represent different time periods spanning the years reviewed. Analysis of the samples showed that for eight of the ten patents, usability had "little" to "no" influence on the patent claim narrative. However, in two patents, usability played a predominant role in defining the claim narrative.

This analysis also uncovered that keyboard engineers are proficient at inventing new ways to solve the same problem (illuminating a keyboard), but are blind to how these inventions could be used in new ways. Only after usability ideals uncovered new issues were fresh claims incorporating illuminated keyboards invented. In saturated domains, such as illuminated computer keyboards, it appears that incorporating UI and UX methodologies in the product development process could enable new patentable claims.

### 6.1 The Patent Analysis

Each of the ten patents were studied and grouped together by how UX/UI issues influenced the claim narrative. In the first group, Boulanger [10] and Brown [11], the word "user" is never specified, but they speak about an "operator" as an extension of their engineered system. For example, "…keys to extend through the openings to be manually depressed by a keyboard operator". Boulanger is only concerned with the systematic thoroughness of the mechanism, not the humanness of the operator.

The second group, Chiang [12], Douzono [13] and Suwa [14] lacks any mention of an operator or user. For example, the Chiang patent states: "Since computers may be used in various environments, such as dark environments, an illuminated keyboard is provided". One may assume that the user in this scenario is considered, but he/she plays no part in the specification of the invention. This team focuses solely on the precise and challenging engineering problem of illuminating a keyboard.

The third group, Howell [15], Zhang [16] and Welch [17], includes the word "user" and "operator" a few times in the document specification, but with limited impact. For example, the Howell patent states: "Portable computer systems are often used in low light situations. In these situations, it is easy to read information shown on the display. However, it is quite difficult to see the keys of the keyboard." In this narrative the user is alluded to but is not a driving factor in developing the claims.

The fourth group, Shipman [18] and Bronstein [19], engage usability issues fully in the patents claim narrative. Shipman dramatically highlights a number of different ways users need to operate keyboards in poor lighting situations. For example: "poor lighting…causes the keyboard operator to memorize the key locations or to strain their eyes." Although he is very conscious of the users needs, neither he nor any of the other inventors or patents mentioned so far have redefined the problem beyond "how to see a keyboard in the dark". It is noticeable that after 30 years of invention in a single domain engineers have produced only technological updates to the same problem.

Bronstein's patent, however, is a radical departure from the previous patents. This patent focuses on usability, which redefines how illuminated keyboards could be used. Bronstein explains that in conjunction with software programs, like tax forms, linking select illuminated keys with the requirements on the monitor enhance usability. He explains the following scenario:

> "A user may be presented with a form on a display screen of an electronic device associated with a keyboard, such as an electronic form. The variable illumination of one or more different keys on the keyboard may increase the user's efficiency in completing the form... The form may require the user enter… numbers in order to complete the form and may require the user to move or "tab" between entries on the form... The electronic device, which may be coupled to the keyboard, may provide a device input to the keyboard instructing that the numerical keys… the "TAB" key, and the "+," "-," and "." keys… be illuminated".

Where the other patents in this set have been developed to optimize a single well-established issue, this user-centred approach engages aspects of a meaningful user experience incorporating enhanced usability, to invent fresh solutions to fresh issues. This user-focused mentality illustrates in part why Apple, the owner of this patent, is currently a leader in the consumer electronics industry.

## 7 INTELLECTUAL PROPERTY AND DESIGN STUDENTS

To educate and protect students in intellectual property matters, the author's academic department has developed a number of proposals. One model mimics the evolutions identified in the legal and cultural changes outlined in this paper. In this case, to overcome the individual inventor scenario projects are sought which allow work in cross-disciplinary development teams on usability or user experience. An example of this collaborative effort can be reviewed in the paper "The Hewlett-Packard Sensory Home Project" [20].

Also, recognizing that intellectual property issues are realistically managed best by the experienced staffs of large institutions and not individuals, students participating in these courses are encouraged to assign their intellectual property rights over to the university who in turn, negotiate all IP issues on their behalf. In the current educational structure, when corporations require intellectual property agreements for sponsored projects, the students, as the owners of their creations, are left to negotiate the terms of the agreement directly with the sponsor. This is a rather one-sided event that typically leaves the students feeling abused.

In the past, it has been demonstrated that students occasionally create work that corporations value and desire to develop further. On these occasions, students enter negotiations on their own behalf (what student has money for an attorney?). Being excited about the request but lacking knowledge and experience they typically overvalue their work, underestimate their rights and botch the negotiations, which benefits neither party. Both parties would be better served if students would allow an experienced attorney to negotiate these situations on their behalf. To address this issue at a university, one might consider reviewing how their university licenses intellectual property.

Large universities typically have Technology Transfer offices that handle processing of intellectual property and negotiating licensing contracts for the inventions created in the university's research labs. For individual players, such as students, to participate in the intellectual property domain in today's environment, they will need to collaborate with an established player, who has benevolent intentions. The Technology Transfer offices found at many large universities could fill this need.

Unlike most corporations, universities typically have generous profit sharing plans with their inventors. At the author's institution, intellectual property based income is shared between the inventor who receives 45% of the proceeds (minus the initial costs of processing the IP), the college of the inventor receiving 27.5% of the proceeds and the Technology Transfer office receiving the remaining 27.5% [2]. Enlisting students in this scheme would seem ideal, however, it requires first that the university be open to engaging with students on this level and secondly that the students are willing to participate in a "share the work, share the profit" venture.

To educate students in intellectual property issues, these same experts could be enlisted to either run a small IP workshop explaining the basics of intellectual property, or provide the professor with materials and guidelines for class presentation. The training would include the basics of patent and copyright law. It could potentially include real contracts that the students would sign as part of the studio course. Students would not only learn about contracts and what is patentable, but also how to search for prior art, understand claim language and perhaps most importantly, begin to understand the value and best use of their creative endeavours.

## 8 CONCLUSION

Students need to obtain a realistic view of the contemporary intellectual property environment and discover how they can effectively interact with it. In the product development world, they will be required to deal with it at one point or another.

First, they need to comprehend that their typically nostalgic view of Doc Emmett type inventors, who create patents, gaining fame and fortune, are extremely rare or even extinct in contemporary society. Second, they need to understand that today's patentable inventions predominantly come from teams of inventors that are usually composed of multi-disciplinary experts. Third, that playing in the intellectual property arena is primarily a game reserved for well-funded institutional players with a well-tuned legal staff. Fourth, that although recent changes in the intellectual property domain are a disadvantage to students, their usability and user experience research skills, as well as, their ability to network with inter-disciplinary peers, will enable contemporary students to create fresh, patentable, product designs.

Finally students need to learn that IP is not a mystery to avoid, but an opportunity they are uniquely qualified to utilize. As students become familiar with the issues surrounding intellectual property, their behaviour should also evolve. An offence taken when one student feels another student has unjustly incorporated her "novel" idea into his work should disappear as well as the often-asked question, "should I patent this".

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# PUBLIC BICYCLES: HOW THE CONCEPT OF HUMAN-ORIENTED "MOBILITY SHARING" TECHNOLOGY CAN INFLUENCE TRAVEL BEHAVIOUR NORMS AND RESHAPE DESIGN EDUCATION

**Alexandros NIKITAS, Pontus WALLGREN and Ulrike RAHE**
Division Design and Human Factors, Department for Product and Production Development, Chalmers University of Technology, Sweden

**ABSTRACT**
Although at the moment an excess of 500 public bicycle schemes of variable sizes operate in almost 50 countries worldwide, the impact of their use on travel behaviour and modal change have neither been studied extensively nor have been understood thoroughly as yet. This work negotiates the initial stages of an international research scheme that means to look into the attitudes and system user experiences (the latter only when it is applicable) that could define the design (or re-design) criteria for three public bicycle schemes in three cities of different size and culture. These systems are currently on three dissimilar operational phases spanning from bidding for funding to actually having a fairly successful system already in place. As a matter of fact, the choice of the three case study cities represent an effort to frame the dynamics of the bike-sharing phenomenon in a micro-scale (Drama, Greece, 50.000 residents), meso-scale (Gothenburg, Sweden, 500.000 residents) and mega-scale (Shanghai, China, 23 million residents) looking also into the attitude-shaping process before and after the implementation of a scheme. This project's didactic role is a twin one; it aims to reinforce education practice on sustainable mobilities design by using student projects as an apparatus for supporting research and promoting urban change in real societal terms and subsequently to integrate the findings of the research into future postgraduate and undergraduate course material. Thus, bike-sharing design, for the means of this paper, aims to serve as an academic platform for integrating and synchronising research and education by promoting a balanced and timely development of technological opportunities that capture the mobility needs of tomorrow.

*Keywords: Public Bicycles, Bike-Sharing Schemes, Travel Behavioural Change, Sustainable Mobilities Planning and Design, Research-driven Design Education*

## 1 URBAN TRANSPORTATION DESIGN AND DESIGN EDUCATION

Governments worldwide are committed to control the ever-rising levels of conventionally fuelled car use amongst their populations. This is due to a conscious attempt to secure that their societies may live in urban environments, which support development meeting the travel needs of the present without compromising the ability of future generations to enjoy the merits of liveable cities. In their armoury policy-makers have a variety of 'stick' and 'carrot' measures to tug and tempt people out of their cars, respectively. Of the former, demand-side measures could force people not to travel by car, or to travel by car less; of the latter, softer measures, which hope to persuade the car user to consider modification to their behaviour including improvement in alternatives [1].

Lately a rapid growth in the number, range and scale of voluntary travel behaviour change initiatives has challenged the assumption that modal shift is only possible through regulatory mechanisms [2]. This means that focusing on how to improve car alternatives is a key in any well-rounded urban strategy aiming to provide equitable transport. There is a need therefore, for design in general, and design education in particular, to be an integral part of reforming conventional transport regimes that have been based on the philosophy of "providing all necessary means of access to private automobiles". This could be achieved by introducing research-driven education, based on specific real-life case study scenarios, that seek to expand the knowledge spectrum of young designers in terms of understanding alternative transport options; options that would serve the emerging reality for creating a more balanced modal share.

Such education should see design in a very distinctive way, which goes far and beyond its original role as a medium that guides product development to optimum levels of performance. Design needs to be re-defined in a way so that it becomes a shared responsibility process, where designers and the society as a whole, develop a sole agenda for user-centred technological innovation. This effectively means that design education would be utilised as a powerful medium to achieve this designers-society alignment, whereas design students could be a very important link bridging design with everyday life and people's specific urban requirements. Moreover, design should be associated not only with the delivery of a good transport mode in terms of producing a well-received product, but it should rather embrace a holistic approach for catering the needs of a road user-centred homogenous product-service system. This different orientation of approaching design could support a systemic educational approach to urban transportation that could progressively facilitate new knowledge generation. This "intellectual capital" will enable the transition from designing for an existing transport system, dictated by conventional car orientation, to designing for a transport system that prioritises alternative product system innovation [3].

More specifically, when design education negotiates urban transportation it should concentrate on studying, improving, expanding and delivering alternatives to car transport options that have the potential to support more sustainable mobility patterns. Public bicycles or bike-sharing could be the very definition of such a transport mode.

## 2 INTRODUCING PUBLIC BICYCLES

A bike-sharing system is a combination of bicycles that can be picked up and dropped off at numerous points across an urban area with an appropriate transport infrastructure built to accommodate their use. [4]. Bike-sharing systems have been introduced as a means to extend the accessibility of public transit services to final destinations in a way that promotes the development of sustainable and aesthetically pleasing urban environments that prioritise people over cars. By providing free or affordable short-term access to bicycles, these systems offer transportation that could eventually substitute short car trips with bicycle rides. This likely mobility scenario could help societies to alleviate road traffic congestion and moderate problems linked with unnecessary car usage like climate change, air and noise pollution, pedestrian injuries and deaths, declines in physical activity and obesity [5]. The most important function of such a scheme is the concept of "sharing" since individuals use bicycles on an "as-needed" basis without the costs and responsibilities of bicycle ownership [6]. This could initiate or reinforce the process of building a culture of shared responsibility for the "well-being" of the scheme and the city's transport system in general.

Recent experiences suggest that bike-sharing systems can act as a door opener for increased bicycle use [7] by being a "living" reminder that bicycle belongs to a city's streets. More specifically, public bicycles have the potential to increase the acceptance of cycling as a legitimate urban transport mode in cities that still lack a good level of bicycle use by introducing a new and attractive system experience. In cities that a good cycling mentality is already in place, a competent bike-sharing scheme could add a valuable element to existing mobility services; something that enhances the transport system's overall potential in terms of providing option value. A public bicycle scheme could work as an initial investment that could help cycling become part of a city's urban identity something that will progressively create the need for more investments aimed to improve bicycle-related infrastructure and services. A public bicycle scheme could also practically facilitate intermodal travelling.

## 3 AN INTERNATIONAL PLATFORM FOR BIKE-SHARING

This work means to describe an international research scheme examining the attitudes and system user experiences (the latter only in cases when this is a viable scenario) regarding public bicycles in three cities of different size. As a matter of fact, the choice of the three case study cities represent an effort to frame the dynamics of the bike-sharing phenomenon in a micro-scale (Drama, Greece, 50.000 residents), meso-scale (Gothenburg, Sweden, 500.000 residents) and mega-scale (Shanghai, China, 23 million residents) looking also into the attitude-shaping process before and after the implementation of a scheme. These systems are currently on three dissimilar operational phases. In Drama they still plan the scheme and are actively bidding for funding it, in Gothenburg a successful scheme is already in place that has been massively expanded over the last three years, whereas in Shanghai public bicycles are still tried out on a smaller scale only in specific areas not centrally located and perhaps are more inclined towards tourist audiences. The analysis that follows purposely focuses on the issues referring primarily to the links of this public bicycle research with design-oriented transport education.

### 3.1 Case Study Gothenburg: Identifying and Eventually Replicating Success

Gothenburg is the second largest city in Sweden by population and the fifth largest in the Nordic countries with a city-based population of 519,400 residents. Gothenburg is situated on the Southwestern coast of Sweden and has a strategic geographical position in Scandinavia, being approximately half way between Copenhagen and Oslo. In terms of climate conditions, because of the moderating influence of the warm Gulf Stream, Gothenburg enjoys milder weather than other cities with similar high northern latitude. Gothenburg is a city with a relatively good level of public services in place, providing a wide range of transport options to its commuters. With over 80 km of double tracks, the blue iconic tram of the city is the largest light rail network in Scandinavia and together with the bus network form the basis of the public transport system. There are also daily boat and ferry services catering the needs of a city that is defined (even in terms of its own name) by river Göta. In early 2013, a road pricing scheme was introduced in the city centre to regulatory enforce in some respect modal change, while parking pricing is another measure that has been spread to all central and residential areas of Gothenburg for many years now [8].

With over 600 km cycling routes, Gothenburg provides an extensive bike road network that makes cycling a valid transport option for the city's commuters. Gothenburg has already in place Styr & Ställ, which is a self-service bike rental system, spread across 57 stations throughout the city centre with approximately 600 bicycles. The system can be accessed 24 hours a day and seven days a week. It is available between 1$^{st}$ of March to 31$^{st}$ of October. Technical support is open at working hours every weekday. In order to access the system, customers have to subscribe to a 3-day pass (10 SEK), a season pass (250 SEK) or special business subscription. As a matter of fact the season pass for year 2014 will cost even less (starting from 75 SEK). The usage price is free for the first 30 minutes to allow for people to experiment without any cost the system. The scheme is financed by the revenue generated from its users and from the commercial billboards placed throughout the city. Approximately 50,000 annual users signed up in 2012 for using this service; this number includes a large number of tourists and is not restrained only to daily commuters. Around 70,000 movements took place on a weekly basis at that time; movement is any case a bike is rented, returned or moved by the service staff from one station to another [9].

The work package referring to Gothenburg's potential for providing an advanced bike-sharing experience reflect a two-step process consisting of a postgraduate student research design exercise and a primarily quantitative online survey targeting the residents of the city in order to frame existing challenges within the first years of the Styr & Ställ's usage. In late 2012 seven teams of four to five young designers, all of whom participated in the Masters course Visual Brand Identity and Product Design being closely guided by the authors, were affiliated with designing an innovative hypothetical bike-sharing scheme for the city of Gothenburg, Sweden, that would have been an upgrade over the existing one. The goal of this course exercise was a dual one. It was designed to provide students with a learning experience that would allow them to develop a theoretical and empirical understanding of: a) how aesthetic and symbolic qualities of products can be used to support and develop the visual identity of brands and b) how human-centred design innovation could provide viable but the same time attractive answers to current (and future) needs for sustainable transport. The second goal of this project exercise was the collection of primary data, through the means of ethnographic studies and interviews with Styr & Ställ representatives and users, and with Gothenburg commuters in general, that would enable the authors to identify the advantages and disadvantages of the current system. On top of that the students designed visual upgrade scenarios for bike-sharing in Gothenburg discussing a lot of innovative ideas like: a) employing intelligent technology applications for improving the pre-service, on-board and post-journey experience, b) introducing fully electrical or pedal-assisting bicycles and c) integrating bike-sharing not only with a city's public transit or landscape but with its very own urban identity. Identifying the problems and opportunities that have been missed thus far, which restrain the scheme's potential to achieve wider societal acceptance, is the basis for producing an improved design approach that could lead to a bike-sharing system capable of attracting more users.

This process allowed this work's primary research tool (which is the online survey) to be timely informed and adequately centred around the real challenges reflecting the use of Styr & Ställ. This subsequent study is goaled towards identifying in a scientifically sound way the attitudes of people towards bike-sharing in general and towards Styr & Ställ in particular, whereas it also means to record the system user experiences of the people that have tried at least once the scheme. This would pragmatically enable the development of advanced human factors design concepts meaning to support the development of the Styr & Ställ system into a more user-friendly and thus societally acceptable means of transportation. The online survey has similar format and contains questions and sections easily comparable with the surveys delivered in Drama and Shanghai. This is a conscious research strategy choice so that the overall study could be cohesive and homogeneous. Another function of the Gothenburg study utilises students as an effective data collection medium but at the same time engages them actively in real research by having them circulating the online survey through their social media applications.

### 3.2 Case Study Shanghai: Learning from Past Mistakes

Shanghai is considered as one of the most rapidly transforming metropolitan environments in the world, with over 23 million inhabitants. In terms of population, it is the largest city in China and has been one of the fastest developing economies globally being the commercial and financial centre of mainland China with the busiest container port in the world. Despite a boosting local economy, the rapid urbanisation has created huge challenges for Shanghai. Environmental degradation, social sustainability and the urban growth itself are issues that need to be taken care of. High density is one of the main features of the city, with more than 3,600 people per $km^2$. The population has doubled during the last three decades and it is still increasing at a rapid pace. Diversity is another exceptional local characteristic. Shanghai is a global city with many different cultures and life-styles, which leads to consequences such as poor material supply, huge need for environment protection requirements, rising issues of public security and disrupted social equality. Increasing population also brings an increasing number of private vehicles and growing conventional fuel consumption. Since Shanghai is a city that looks to be in the frontiers of sustainable and inclusive urban development, it needs to continuously revisit its policies, its urban infrastructure and its built environment service provision that could produce social inclusion problems and have feasible design solutions in place to overcome any city-induced mobility related barriers [10].

Bike-sharing is among the transport interventions that actually are being prioritised by the Chinese Government in an attempt to revive the iconic image of China in terms of being "the kingdom of bicycle" [11, 12]. For example, Hangzhou Public Bicycle, located in a metropolitan area populated by nine million residents, is the largest bike-sharing system in the world already, with 66,500 bicycles operating from 2,700 stations (early 2013 figures). For the means of the 2010 World Expo, Shanghai launched a limited public bicycle programme that failed to transform to a citywide bike-sharing mode. Nowadays public bicycle schemes of much lesser scale than the size of Shanghai could dictate are running independent from each other in the districts of Minhang (the bigger one), Pudong, Baoshan and most lately in Shanghai's former French Concession targeting only tourists (initiated by Xuhui District's Tourism Bureau) [13]. Therefore, there are grounds to believe that there is a lot of yet unrealised potential for bike-sharing in Shanghai and a research study trying to indicate drivers and barriers to its acceptability could be a key for a more citywide user-centred public bicycle plan.

The Shanghai study aims, through the use of a primarily quantitative online survey targeting people commuting within the city's premises, to capture the public acceptance that a citywide bike-sharing programme could have. In a secondary stage the work could be also attempting to record the system user experiences of the people that have tried at least once the district-based schemes. Masters and Bachelor students of Tongji University's College of Design and Innovation will be distributing the questionnaire across the city being utilised as an effective data collection mechanism for the means of this work package. The students' involvement also has to do with assisting in the translation of the questionnaire and of the results that have a more qualitative nature. This research exercise will be linked potentially with a postgraduate design education module and could be assessed by their educational tutors so that it would contribute in the module's final mark for the students.

### 3.3 Case Study Drama: Starting Something New and Exciting

Drama is a city situated in the North East part of Greece next to the Greek borders with Bulgaria. It is the capital and the economic centre of the regional unit of Drama, which is part of the East Macedonia and Thrace region. Drama is distant from the Greek capital Athens (670 km) but relatively close to Greece's second largest metropolitan center Thessaloniki (158 km), whereas the closest airport and sea port are located in Kavala and Chrisoupolis 37 km and 68 km away from Drama respectively. Drama has a city-based population of 45,828 residents but the overall municipality population, which includes 14 suburban communities in close vicinity from the main city, is 58,944 inhabitants [14]. Until recently, the economy of Drama relied heavily on the local paper and textile-clothing production industries. However, these industrial production entities have either ceased their operations being victims of the Greek financial crisis and the steep competition from antagonists from abroad or moved across the border to Bulgaria in order to minimise personnel costs. This is something that has affected adversely the local economy drastically reducing employment provision. Recently, there have been efforts to exploit the rich local natural environment and to develop eco-tourism something emphasising the need for commitment to a more sustainable resource management strategy with mobility being one of those resources [14]. Drama despite its manageable size has some traffic congestion problems in its city centre due to their citizens' over-dependence on private vehicles. Public transport is only offered by the relatively unpopular bus services mainly used by students and older people and taxis.

Planning and subsequently implementing a small-scale public bicycle scheme, referring to a system of 50 to 60 bicycles in five stations spread in the most defining destinations of the city, is one of the newest additions to Drama's urban transportation strategic initiatives. Identifying the possible barriers that could reduce the public acceptability of a bike-sharing scheme and understanding thoroughly its potential for generating modal shift would enable the city to prioritise and customise the scheme's design requirements. Examining the attitudes of Drama's road users and tax-payers on cycling, bike-sharing and its suitability for Drama was therefore a timely and pragmatic need for producing user-oriented transport innovation.

The work package dedicated to Drama meant to fulfil this very need. It was founded on a primarily quantitative survey formed by 20 questions the majority of them employing 5-point Likert scales. The questionnaire was available in an online form and via one-page hard copies. The online survey was accessible through the official webpage of the Municipality of Drama, while paper-based questionnaires were distributed together with the water and sewage bill letters to many households in Drama and via the local organising team consisting among others by the first author, the president of the civil servants of the regional unit of Drama, a future Doctorate student in the field of transportation engineering and a number of undergraduate students. This engagement was a characteristic example of linking research with research-driven education since a student preparing to pursuit PhD studies had the opportunity to experience, at first-hand, a wide range of research design and data collection challenges and learn how to tackle them in real terms. The high-school, college and the local technical University's students that were actively involved in the distribution of the survey and also the student population that could be interested in pursuing research in the future have been invited to participate in a series of workshops/visualisation clinics that are planned for the dissemination of the work (reflecting the statistical analysis of 640 fully completed questionnaires) to the people of Drama. An event for presenting the initial findings of this work in the City of Drama and the local schools was delivered on May 2014 where the pre-Doctorate research student had a considerable engagement.

## 4 CONCLUSIONS

Bike-sharing is an inner-city travelling mechanism that provides a man-powered, and in some cases an electrically-motored mode, which means to replace conventionally fuelled car trips with bike rides. This is a modal change aiming to create less polluting and congestion-free road user experiences. In addition, this urban mobility system is based on the concept of "sharing" that is about disengaging private ownership from the actual usage of a vehicle, something that in principal could be providing flexibility and an equitable means of access to cycling. Nonetheless, this "sharing" notion also creates the need for the users to co-exist and co-function harmoniously in a system that they can see as "their own local system". Thus, a bike-sharing scheme is also an apparatus for promoting a philosophy of shared responsibility for catering the transport related needs of urban societies. Alternative to car mobility in general, and vehicle-sharing schemes in particular, have a central role to play in the future of sustainable cities, but it is only through the understanding and acceptance by the people that these will succeed [15]. By engaging students in this process of co-creating an “understanding” framework (or in this case even a “sharing responsibility” one) this work influences a new generation of designers to be part of a timely and meaningful educational platform for dealing with urban transportation challenges. Crafting more transparent sustainable urban development pathways is more achievable if education becomes, in pragmatic terms, the intermediate step between research and design practice and students become the link that relates the design process to the society.

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Chapter 4

# LEARNING SPACES

# SUPPORTING THE EARLY STAGES OF THE PRODUCT DESIGN PROCESS: USING AN INTEGRATED COLLABORATIVE ENVIRONMENT

**Julian MALINS[1], Aggelos LIAPIS[2], Julia KANTOROVITCH[3], Panos MARKOPOULOS[4], Richard LAING[1], Alexandros DIDASKALOU[5], Karen Coninx[6] and Fiona MACIVER[1]**
[1]IDEAS Research Institute, The Robert Gordon University, Scotland
[2]INTRASOFT International SA, Greece
[3]Teknologian Tutkimuskeskus VTT, Finland
[4]Technische Universiteit Eindhoven, The Netherlands
[5]TDesignlab(edg designlab EPE), Greece
[6]Universiteit Hasselt-tUL-iMinds, EDM,Belgium

**ABSTRACT**
Existing technologies designed to support professional product designers focus mainly on the modelling stages of the design process, while the early conceptual stages remain relatively unexplored. There is a need for seamlessly integrating product development tasks into a comprehensive collaborative computer supported design environment that can assist professional product designers. To address this need, a new research and development project funded by the European Commission under the 7th Framework programme has been launched, entitled Collaborative Creative Design Platform (COnCEPT). The research aims to address the technology gap by defining a flexible framework, which can serve as a blueprint for the development of efficient collaborative computer supported environments. The COnCEPT platform will use advanced data-mining algorithms to find appropriate text and visual information to support product designers at the early stages of the design process, making use of past solutions, market data and new emerging technologies. The software will convert the available and contributed information into a form making it accessible to the design team. The project will investigate which interaction techniques are most suited to specific situations and activities, and how they can be combined in one integrated environment. This paper identifies the key design challenges facing the project team, and describes the theoretical basis for the COnCEPT platform's development. The paper also sets out the methodological approach that has been adopted by the researchers, which includes specialists from design, architecture, informatics, and interface design. The research will be evaluated with professional product designers and undergraduate design students. The potential use of a collaborative design platform and its implications for design pedagogy is also explored in the paper.

*Keywords: Collaborative Product Design, Computer Semantics & Ontologies, Design Pedagogy*

## 1 INTRODUCTION

There have been many attempts to model the design process and to understand the nature of creativity [1] [2] [3]) within professional design practice. The design process itself is often visualised as a form of flow diagram with iterative loops indicating stages where divergent thinking is followed by convergence on particularly promising ideas. The UK Design Council's well known 'double diamond model' provides an example of a simplified approach to idea generation for product development [4]. Most models don't describe the relationship between client and designer prior to initiation of a brief. The starting point of such design process models is often the identification and understanding of a problem or challenge that requires a design solution. The end point of these models is the implementation of a design solution. The following stages often feature in these design process models:

- Problem identification
- Ideation (divergent generation of ideas)

- Synthesis (convergence on solutions that satisfy the initial brief)
- Iteration (experimenting with multiple solutions)
- Prototyping (both virtual and physical)
- Selection and implementation

This paper describes an EC funded project (COnCEPT) which aims to develop tools specifically designed to support the early stages of this design process model which will include: the analysis of the initial brief; the generation of textual and visual information around the brief; idea generation; and the tracking of contributions made by the design team to projects through to completion.

A wealth of software already exists to support 3D design visualisation and modelling, including applications supporting both virtual and rapid prototyping. Commonly used examples include programs such as RHINO, AutoCAD, Alias, and 3D Studio Max. In addition, software exists to support project management within companies such as Microsoft Project, Basecamp and Merlin. Applications are also available that are designed to support mind mapping, concept mapping, and storyboarding. The COnCEPT project described in this paper aims to develop a holistic environment designed to support collaborating design groups by making use of advanced information retrieval and visual processing algorithms.

The variety of design process models to date is better fitted to design teams working as a collocated team belonging to a single organisation. There is a discernable trend towards open innovation processes that include multiple stakeholders consisting of small design teams collaborating with other stakeholders. In response to this, there is a need for the development of tools that support the work of distributed design teams, collaborating over distance and across organisational boundaries.

The paper considers collaborative design working, and the requirements of professional designers specifically within the product design domain. The authors describe the methodological approach of the project and the proposed solutions for supporting the creative process. The implication of the resulting software for an educational context is also discussed.

## 2 THE EARLY STAGE OF THE DESIGN PROCESS

Design briefs vary considerably from highly specific sets of specifications to very open non-specific outlines for new products [5]. Typically, the formulation of a brief is an iterative process that is low in structure and requires considerable effort on behalf of the designer and the commissioners of the brief to create a common ground. A design brief that is very open and non-specific puts a greater onus on the designer to add more detail. The degree of dialogue between designers and the commissioners of the design brief will vary considerably from project to project and is dependent on many factors including the degree of trust and experience between the stakeholders [6] [7]. In addition, participants within the design team will often be drawn from a range of professional design backgrounds, this being particularly true within architectural design processes, where the nature of design, even at the conceptual stage, will include the need to consider technical, social, aesthetic and economic drivers and constraints [8]. Since the brief itself must be a key starting point, tools that support a dialogue between client and designer may be a valuable resource.

A lot depends on the experience and skill of the designer at this stage, but given the high stakes of getting the design brief right, it is worth exploring how technology can support this process. For example, Malins and Liapis [9] developed an algorithm that would identify key words automatically and undertake a web search. However it was found that design teams preferred to interpret the document first to identify their own key terms. Starting points for the interpretation of the brief are always highly individualistic. Designers will bring their own experience to bear on the interpretation of the client's requirements.

A common starting point for many designers is to search for images that relate to key terms or analogies. From an initial search, visual images may be used to stimulate new ideas based on mood-boards or storyboards. These may serve to form associations and support the ideation process. Algorithms that search for similar, rather than identical, images can be very useful when stimulating associative thinking [10] [11]. This is a process that is not normally formalised as part of the design process. Sometimes it is referred to in terms of serendipity or chance, but in this case it is a way of generating and refining visual imagery based on searching either the designers own image repository, or the wider internet. Before the advent of large visual repositories, designers might have cut images from magazines, made sketches and mind-maps. Idea generation techniques such as mind-mapping [12] and brainstorming [13] are standard practice amongst designers. Stand alone software for mind-mapping and mind-mapping tools are now much more common, for example, Inspiration, Mindjet, Mind42 and Mind Manager. Early design processes make heavy use of scenarios and sketching. Both are low cost representations of design concepts that leave a lot of room for designers to choose the level of detail they use for different aspects of their design, and are intended primarily as a communication tool and a basis for dialogue, rather than as a design specification.

## 3 SUPPORTING CREATIVITY

The difficulty with theories surrounding creativity is the lack of a clear definition of the term creativity [14]. What is perhaps easier to model is different forms of thinking, for example intuitive thinking, which can be stimulated by the random generation of images that allows new associations to be made based on existing memories. An alternative model uses more systematic methods to force the generation of ideas, such as the use of a morphological matrix [15] or makes use of case based examples such as TRIZ [16]. Applications exist to support both the use of randomised images and more systematic approaches. In recent years many different organisations have produced sets of cards designed for a similar purpose see for example Innovation Management's card decks[1]. In addition to searching for whole images, designers may have a requirement to search for elements within an image. These might relate to a particular shape, colour, composition or a more abstract characteristic of an image that suggests a particular emotion or quality. The COnCEPT platform will aim to provide sophisticated search tools that allow designers to find imagery based on the properties of the image, allowing them to make more use of abstract concepts for stimulating ideas.

## 4 COLLABORATIVE INTERDISCIPLINARY WORKING

A major challenge in distributed design teams working together, is the difficulty of exchanging information that is relevant to design, and actionable by a distributed design team [17] [18]. Communication over professional and organizational boundaries can be difficult, precisely because people are distributed over multiple locations, or because they might not be motivated to 'give away' their work [19], or simply because there is no easy way to share their work. Amongst design companies this accumulated design knowledge is a key asset that is not always optimally used. Design knowledge transcends reports or other forms of documentation, that represent formally documented and shared knowledge, onto 'folklore' and 'awareness knowledge' that is shared implicitly within a design team. This knowledge in a technology oriented innovating environment, may refer to specific technologies, their capabilities and performance, experiences from past design projects and local workarounds to problems, or simply awareness of the activities of co-workers. Design knowledge is very difficult to quantify and convey as it pertains to tacit knowledge, which is knowledge that is deeply rooted in action, commitment, and involvement in a specific context. Issues surrounding communication become critical when designers are not collated and the resulting problems may be costly in terms of time and money. For this reason technology is required to support capture, dissemination, and reuse of design knowledge across the design team. Similar issues have arisen with the design of software. For example, Terveen et al. [20] studied software development processes and examined the sharing of folklore knowledge that is usually not written down; rather, it is maintained and disseminated informally by experienced individuals. Nevertheless, their solution to support software developers was based on recording and providing written textual advice. Currently, such practices are easily supported through widely available groupware and collaborative editing tools, such as Wikis or social media.

While the flexibility and fluidity of the capture and display of such information may make it more viable than the formal documentations, text representations are not ideal for supporting the capture and reuse of design knowledge.

Creating and sharing design knowledge across distributed design teams needs to tap into media more appropriate for design knowledge but also to foster and build upon the social interactions between designers and stakeholders. Nonaka's Dynamic Theory of Organization Knowledge Creation [21] identifies two dimensions which characterize this process: one is the distinction between tacit and explicit knowledge and the other concerns the degree to which knowledge is created individually or by

[1] https://innovationmanagement.se/2012/11/12/21-card-decks-for-creative-problem-solving-effective-communication-strategic-foresight/

a community of interaction. He then identifies four modes of knowledge creation that should be supported. (a) Socialisation: tacit knowledge can be shared between individuals without being formally documented. Technology can help by mediating, facilitating and expanding these interactions. (b) Combination: explicit knowledge sources can be aggregated, reorganized, or modified, to create new insights which is something that media can support (c) Externalization: tacit knowledge is made explicit, through attempts to communicate it and codify it (d) Internalization: an explicit form of knowledge is practiced and becomes automated.

An organization can enhance its knowledge by encouraging individuals to experience and practice, to interact, and especially to share knowledge, making what is an individual's own knowledge shared, and allowing it to be enhanced through the four mechanisms identified above. Support for design teams needs to address not only appropriate design representations, but to consider their capture and use in the context of knowledge sharing and the social interaction surrounding distributed design teams, and the complications arising from working across organizational boundaries.

Collaborative working may refer to an individual developing a design that is then presented to colleagues who may be asked to contribute in some way, for example, to provide feedback. An alternative form of collaborative working involves the development of a single design by a number of individuals working synchronously or asynchronously or sometimes referred to as distributed collaborative working. The COnCEPT project is aimed at supporting either of these scenarios. Providing support to a group of individuals working on a single design from different locations presents considerable challenges. An environment that can keep track of multiple contributions, whilst providing related information, is seen as a valuable addition to the designer's toolkit. The research that is being undertaken by the COnCEPT project is looking closely at the nature and types of collaboration, which are commonly seen within design consultancies, to ensure that the tools that are developed, are appropriate for the product design domain.

The COnCEPT platform has been conceived as a set of tools aimed at supporting product designers, however that also implies a considerable amount of interdisciplinary working. The COnCEPT project itself provides an example of interdisciplinary development. It involves the close collaboration of expertise drawn from Design, Architecture and Informatics. The designers on the COnCEPT project are concerned with gaining an understanding of the end-users' requirements and translating these into a set of specifications which can be developed into software solutions with intuitive interfaces. This requires bridging barriers caused by contrasting research paradigms.

## 5 SEMANTICALLY DRIVEN SYSTEMS

The initial stage of the design process relies extensively on knowledge-exploration. Many studies have demonstrated that designers make intensive use of analogies, adapting design solutions from other fields to find new design solutions [22]. Moreover, it was shown that often the most creative analogies are those that are made between unrelated knowledge domains [23] [24]. Often the problem or desired product is not presented to designers with a detailed specification, rather, it results from uncertain real-world situations that are ill-defined. The formalization of problems requires that alternative viewpoints of context be taken into account. To achieve appropriate solutions, good communication mechanisms between designer and client are critical, making use of the client's knowledge and experience. As the designer proceeds from the problem analysis stage to the development of concepts, the knowledge search-space becomes narrower, more structured and domain specific.

The critical information being sought by the designer may be embedded in part of a document, image, sketch or even a piece of music. One way of searching for this critical data is by making use of the meta-data attached to these resources. Meta-data can be in the form of key words or tags. In addition the visual properties of an image can also be used to specify search criteria. Availability of access to large repositories of information is an essential resource for a design team. The type of information that designers may draw on to support their creative process might potentially include visual resources, including stylistic information, using for example, colour, shape, behaviours and other properties discussed previously. The quality of the meta-data attached to information, directly affects the relevance of any particular search that is undertaken.

Existing web search engines and databases are very effective at providing simple ranked lists of results. In the context of a creative task however, the information needed may be only partially specified, which creates an additional challenge for the design of search patterns. As the creative search is a very subjective and personal process, tools that allow customisable searching are required.

The COnCEPT project will employ semantic technology to describe resources that will allow the user to align their search requirements corresponding to formal conceptual models or ontologies. The methods are based on semantic annotation using ontologies that are recognised as powerful tools that can assist with the processing of information resources. The system will allow for the development of a more "intelligent" or more machine interoperable, effective and meaningful way of searching for information [25]. Annotations with well-defined semantics are a requirement to ensure the interoperability of information that is consumed, and for sharing meanings in the collaboration design community. Describing explicitly the relationship amongst multimedia resources, visual content and other support material is supported by recent advances in Open Linked Data technology [26]. The digital content from companies' internal repositories can be linked to each other and to other useful knowledge databases and cross-application domains. However semantic annotation presents several challenges that will be tackled by the research undertaken for the COnCEPT project, such as usability and the maintenance of conceptual models.

The usability aspect is related to human involvement in the generation of semantic meta-data. It is unrealistic to expect designers to spend a lot of their time annotating resources, however this could be made easier if they could make use of a natural intuitive interface. If the Concept platform is to be useful, it should provide where possible a degree of automation in the process of knowledge, whilst reducing the need to annotate material in use.

The knowledge management framework envisaged for the Concept platform will not be able to address all the designer's needs across all application domains. The knowledge management framework will remain domain specific. However, it will be possible to extend the COnCEPT platform to other knowledge domains over time.

## 6 IMPLICATIONS FOR DESIGN PEDAGOGY

Professional product design is increasingly a collaborative interdisciplinary activity. Providing a learning environment that accurately simulates the professional context whilst allowing for individual development and assessment of progress, can lead to disconnect between the needs of the academic environment and that of professional practice. The COnCEPT platform may be used to provide an environment to support collaborative learning that can be used to overcome some of these tensions by making it possible to track individual contributions to student projects. A common problem for students working within a computer environment is the tendency to overwrite designs thus making it difficult to track the student's development and to provide appropriate feedback. The system simulates a professional product design context and makes it easier to re-use solutions from other domains.

## 7 CONCLUSION

The COnCEPT project will provide a powerful set of tools to support the early stages of the product design process. The project's emphasis on user-centred design means that the resulting interfaces will be intuitive and take into account working practices within the professional product design domain. Unlike conventional search engines or project management software, the COnCEPT platform aims to support the creative process by generating relevant information either in the form of text based documents or visual resources. In addition the platform is being designed to support collaborative distributed working across interdisciplinary teams. By designing tools for a specific design domain it is anticipated that targeted solutions may be developed where these will have wider implications for professional design practice, teaching and learning.

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# UNDERSTANDING THROUGH MAKING

**Julian LINDLEY, Richard ADAMS, John BEAUFOY and Stephen McGONIGAL**
University of Hertfordshire

**ABSTRACT**
This paper's core theme is incorporating an empirical approach in the understanding of physical value(s) within Product Design (PD). It is a reaction too, and an acknowledgement of the changing nature of both the students previous experiences and the value of design to the modern world. With the former, some applicants lack the breadth of basic skills in drawing, making and experimentation. Indeed many lack a curiosity which is natural to design. This is in part due to the diminishing number of applicants from Foundation Courses in Art and Design (United Kingdom). These pre-degree courses encourage experimentation and play in understanding materials and structures. Another observation is that design has progressed beyond the production of artefacts to a process of problem identification and solving [1]. In this context Sustainability, Brand and Human Centred Design are all common themes within design curricula. However focusing on these in an already congested curriculum has left some of the basic skills and investigations lacking in students vocabulary and skills within design. This paper outlines a way in which an understanding of structures and objects can be achieved. Two projects are cited, firstly a project which gets students to think with their hands and make quickly. The second project builds on this experience with a mechanical design challenge, that of an Automata. The combination of these projects equips students with a preliminary understanding of construction, mechanics, materials and aesthetics. This is a starting point for understanding the physicality of artefacts underpinning PD Education.

*Keywords: Making, Playing, Mechanics, Re-use, Structure*

## 1 INTRODUCTION

It can no longer be assumed that students entering Design Education have an experience of experimentation with materials and structures that is, making. In the UK this can be attributed to two causes (amongst others). Firstly more applicants come directly from School. This is in contrast to previous years when students spent a year on Foundation Courses learning to have an inquisitive mind and play with materials. Research by Wilgeroth and Stockton [2] supports this view with decisions on why students study PD at degree level being arbitrary rather than a knowledge of and application of the subject. Although in schools students are taught design methods this is an academic approach and many only experience real objects when making their final pieces. Secondly we live in a throw-away culture. If a product breaks or fails it is easier to purchase a new one rather than service or repair. This has removed the inherent ability to tell if something is structurally 'right' and basic understanding of construction.

The authors have taken steps to address this shortfall by introducing a broader approach to 3D in the early stages of the Degree Programmes (BA Product Design & BSc Industrial Design). In the instance of this paper, two projects are cited which together introduce students to an empirical approach to materials, mechanisms and structures.

The first project is a quick construction project, getting students to design by making. In essence the project is about the deconstruction and re-constructing of chairs. Based on the work of Martino Gamper [3], students are challenged to make new chairs using discarded and broken chairs as source material. Within this construct issues of material and object value can be discussed as well as product lifetime, product evolution and second life.

The second project involves simple mechanisms. With this project students start investigating on paper but quickly need to develop with simple mechanical mock ups both in 2D and 3D.

## 2 PROJECT 1: DE-CONSTRUCTED CHAIRS

### 2.1 Martino Gamper

The inspiration for the project was the work of Martino Gamper who challenged himself to make 100 chairs in 100 days [3]. The final output of 100 chairs (Figure 1) created a challenging visual feast. Each 'new' chair's visual language played on the echo of past chairs as much as the new forms created. Viewers perceptions are based as much on their own memory as the work in front of them. Some contained visual puns while others challenge our notions of what a chair actually is.

*It is possible on first glance to see the chairs as assemblies of diverse elements, yet on the second to perceive them as singular pieces. To report on only one of these aspects is not enough* [4].

However the questioning nature of the project is what makes it valuable, Gamper himself states:

*The motivation was the methodology: the process of making, of producing and absolutely not striving for the perfect one.* [5].

The starting point for the students was intended to be very different in methodology from the processes that they had been taught in school.

*Figure 1. Work by Martino Gamper*

### 2.2 De-construct, Re-construct Challenge

The project brief was quite straightforward, groups of students (2 – 3 per group) were given discarded chairs and told to use these as source material to make 'new' chairs. The time allocated was three days.

By referencing Gamper's work in the project introduction allowed the staff to explore the notions of heritage, structure and visual language prior to the commencement of the project. Students were not trying to design chairs but create them. That is the final objects evolved from playing with existing materials each containing their own notions of form and language. Students were also constrained by the source material, no other materials could be incorporated, the only additions were fixings. This was emphasised by the short timeframe and the immediacy of physically taking chairs apart and reconstructing them. Essentially the students were taken on a journey of discovery through deconstruction and reconstruction with their own intuitive design sensitivities guiding the design decisions. This approach echo's that of Sjøvoll and Gulden [6]. This is an empirical approach and the sketchbook was not used to design but occasionally to note the ideas found through making or resolve a construction detail.

Students assumed that the conclusion of the project was the delivery of a chair or chairs. However as the project generated a large amount of 'waste or scrap' material they were further challenged to, in three hours, use this to make more chairs. This additional challenge forced the students to work even quicker, making decisions with their hands. Interestingly some of the results (Figure 4) were as successful as those which evolved over three days (Figure 3). This also made the students aware of what they had learnt over three days could now be applied almost subconsciously in this new challenge.

*Figure 2. Experimentation in the studio*

With a large number of chair constructions to reference and analyse, the de-briefing session unpicked the value of the project and introduce concepts from heritage and sustainability. This ‘Crit’ session was an important teaching aspect of the project. These themes included:

- Construction.
- Balance and harmony in 3D structures.
- Material usage and quality.
- Heritage.
- Visual Languages.
- Speed of decision making.
- Design process and the value of making as part of this rather than the result of it.
- Need/Purpose.
- Re-use and sustainability.
- Thinking with your hands.
- Chairs.

The project has now been run over four years, with old constructions used as source materials for the next project.

The resulting objects were used in a group discussion starting with recycling, re-use and product lifespans leading into a broader debate on what was meant by Sustainable Design [7] [8].

*Figure 3. Final Chairs, 3 Days construction*

*Figure 4. Final Chairs, 3 hours construction*

# 3 PROJECT 2: AUTOMATA

## 3.1 Purpose

The second project, 'Design and Make an Automata', demanded a deeper level of considered intellectual engagement with the challenge. This project with two specific stages, Stage 1 'Research and Design' (six weeks duration part-time), Stage 2 (six weeks duration part-time) 'Build your Automata'. There was a design review after the completion of Stage 1. The project references the work of Cabaret Mechanical World [9] and Lawrence and Alexander [10]. These advocate the playful nature of Automata where the excitement is gained from the simplicity of mechanism and humour in the moving stories.

Stage 1 needed to be a concept generation phase followed by simple lash ups to explore mechanisms. This involved a reflective loop where ideas which theoretically worked in sketch sheets needed modification after the first iteration in 3D materials. This design phase is important as Rodgers and Milton observe:

*Product design is a three dimensional discipline, and while the immediacy of marker renderings and the visual gloss and ease of CAD offer huge possibilities, it is essential that designers model their concepts physically and test them in the real world.* [11].

The connection between the sketchbook and workshop became strong. The success of the mechanism depended more on the ability to adapt through making than an initial understanding of mechanics. Overcoming mechanical difficulties, lack of accuracy in the workshop, reflection and adaption were all part of the learning curve indeed it teaches students to develop strategies to cope with failure. One key value of the project was in teaching students the relationship between sketchbook and making while introducing a hands-on approach to the understanding of simple mechanisms. Students also gained an awareness that theoretical ideas do not always work in practice but need modification and evolution.

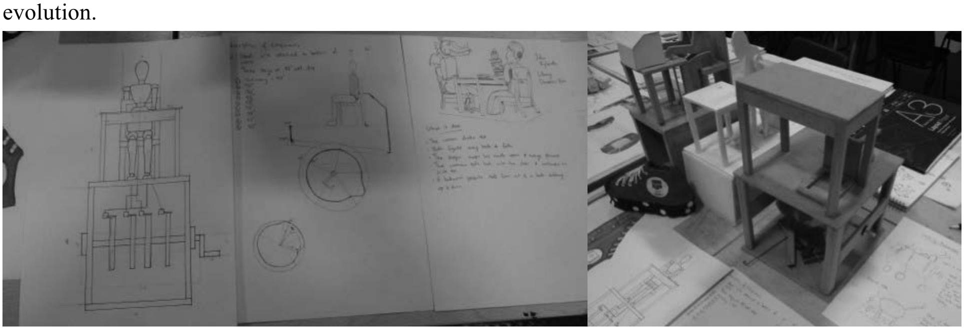

*Figure 5: Automata, Sketches and Lash-ups*

Stage 2 utilised the knowledge of what worked and what did not work in 3D to construct a finished piece. This again involved adaption, while an emphasis was placed on the visual appearance and craft of making.

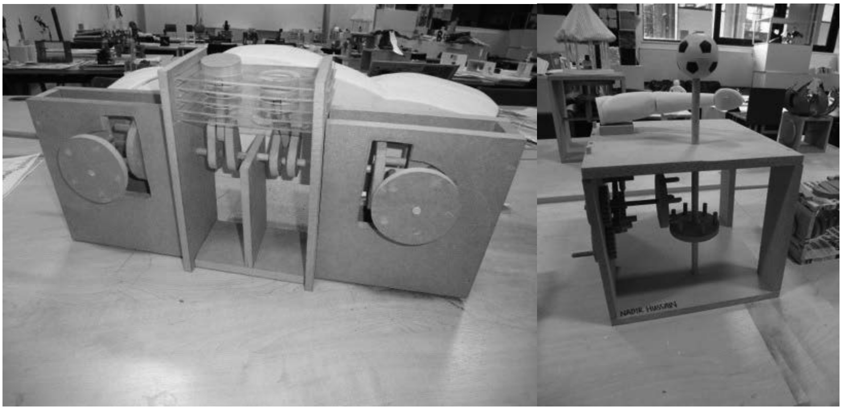

*Figure 6: Automata, Final Models*

## 4 HOW THE PROJECTS LINK WITHIN THE CURRICULUM

Design Education is about equipping students with skills, contextual understanding and creative processes to address the challenges put to them in their professional lives. This need to work in and test within the physical environment is critical in both ID within industry and the training for it [12].
*Whilst designing in the 3D digital environment allows for a faster and possibly more fluid process, we still have the need for the real object as seen in the 'real' world……..*
*………This 'hand's on' approach can be used to finalise any design problems that may arrive during the digital environment, one such example is scale or fit.* [12]
Both projects were set tasks to first year students of Product and Industrial Design as an introduction to 3D, the workshop and making as a valuable design method. Together they form a holistic approach to 3D from experimental to technical, with making and an ease of using a machine workshop part of the learning curve. The two projects explore different aspects of materials, structures, mechanics and making. The first, deconstructed/reconstructed chairs, forced students to experiment and work quickly learning by their mistakes. The second was more prolonged allowing students to generate ideas in 2D while putting these into practice in 3D. This became a circular process with students working between the two approaches. The work underpins the projects set throughout the three year degree programmes.

## 5 CONCLUSION AND REFLECTION

It is important to keep PD & ID Education rooted in the physical world as ultimately a large percentage of the work of designers is realising objects. As designers rather than engineers, the understanding must come from a 'hands-on' approach to learning through making rather than a quantitative delivery of the subject. Developing an intuitive understanding of materials and structure is paramount to success. This in itself becomes an important method within the design processes used by designers.
As these two projects are set early in the three year degree programme(s) it embeds the connection between creating and experimenting in 3D within the students design processes. This is evident in later projects where students use simple models to test ideas and evolve designs. This is different from using the workshop to produce final prototypes or presentation models. The fluidity between 2D and 3D work underpins our approach to product design.
Finally the paper has discussed how to introduce an understanding of making but not delved into why design. The value of making is best summed up by Daniel Charny in an introduction the 'Power of Making' exhibition at the Victoria & Albert Museum (2011, London):
*It is one of the strongest of human impulses and one of the most significant means of human expression. To some, making is the fountain that releases creative ideas; to others, making is about participation in society as well as defining personal identity. To most of those who make, though, it is*

*likely that they do not think of it as a creative activity. It is their way of making a living – an absolute necessity* [13].


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All product and industrial design students at the University of Hertfordshire. Also anyone and everyone who has donated chairs!


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# THE WILD, THE PUB, THE ATTIC AND THE WORKPLACE: A TOOL FOR NEGOTIATING A SHARED VISION ON CREATIVE LEARNING SPACES

**Bruno SETOLA**[1] **and Bas LEURS**[2]
[1]Willem de Kooning Academy, Rotterdam University of Applied Sciences
[2]Creating 010, Rotterdam University of Applied Sciences

**ABSTRACT**
A learning space can be configured by either defining use through design or through use. When a creative learning space is *defined through use*, its configuration and use conditions need to be negotiated. In this paper we present a tool that helps *define the use* of a creative learning space *through use* in terms of coordinating the negotiation process. This tool is composed of four metaphors: The Wild, The Pub, The Attic and The Workplace. Each represents a stage of a learning journey. These metaphors help establish a common ground among a multi disciplinary group of students. Twenty-five art and design students used this tool during an eight-week elective course that investigated the configuration of creative learning spaces. From their experiences, students identified a number of principles and it helped them reflect on what constitutes an engaging learning space. Notably, the dynamics that come along with the *use* of the space *through use* are also reflected in the negotiation process. When the use of the space is changing, the rules of the game need to change as well. Moreover the dynamics of use stimulate participants to "define rules through use".

*Keywords: Learning spaces, metaphors, shared vision, negotiation tool, user participation*

## 1 INTRODUCTION

A growing body of research shows that the physical properties and configuration of learning spaces have a significant effect on the creative achievement and overall performance of design students [1, 2, 3]. Moreover, a learning space is a change agent, it influences its users and their activities, which in turn have agency as well [4]. In its use, a learning space is primarily configured by "defining use through use", rather than "defining use through design" (see [5]).

In our view the notion of *defining use through use* underscores the importance of a user centred bottom-up approach where ever-changing creative practices are the driver for ever-changing creative spaces; this is in contrast with traditional top-down decision making that aims to set fixed design standards. This means that the configuration and conditions of use constantly have to be negotiated with a variety of stakeholders (e.g. students, teaching staff, management, planning and support staff). These stakeholders however, may stem from different domains, speak different jargon, hold disparate representations of the world, or have different – and perhaps even conflicting – goals and interests. This leads to the question that is addressed in the current work: how to facilitate such negotiation process in terms of developing a shared vision on learning spaces in design education?

The occasion that opened up avenues to more explorative research came when the director of facility management asked us to develop a solution that stimulates students to clean up their classroom. When we inquired students why they littered the classroom, they frankly answered: “it's not our space”. This led us to believe that the focus should not be on providing extrinsic motivation to clean up their litter, but rather on intrinsic motivation by developing a sense of ownership. This much larger scope would clearly benefit from research into what constitutes a learning space that is recognized by students as their own.

## 2 MODEL DESCRIPTION

What constitutes an ideal space for an engaging learning experience? Kolb observes: “learning is best facilitated in an environment where there is dialectic tension and conflict between immediate, concrete experience and analytic detachment.” [6]. So we studied Kolb's four stage learning cycle to elaborate on his observation. While scrutinizing Kolb's learning cycle, it occurred to us that his abstract terminology would inhibit our efforts to share a more experiential view with other stakeholders.

In our practice, as design educators, we use a lot of visual thinking and storytelling. It made sense to us to let go of Kolb's terminology: *concrete experience, reflective observation, abstract conceptualism* and *active experimentation*. Instead we reframed the learning cycle as a learning journey in which each stage is represented as a metaphor: "The Wild" (Concrete Experience), "The Pub" (Reflective Observation), "The Attic" (Abstract Conceptualism) and "The Workplace" (Active Experimentation). The metaphors represent a learning journey that can be described as follows:

> *In the real world we experience our environment first-hand in The Wild. What better place than The Pub to share our experiences and compare them? This is where stories are told and nobody judges us because all experiences are equally valuable as a starting point for reflection. Once we are in The Attic, we analyze what was shared and compared in The Pub. On a more abstract level we evaluate what is generally valid about what we have seen and heard. With these observations we develop mental models of the real world. After The Attic, it is time to go to work in The Workplace. This is the place where we prepare ourselves for our next trip into The Wild. In The Workplace we make plans and create prototypes. These plans and prototypes help us cope with the wilderness that the world holds, while they also allow us to initiate a change in it. And when we bring our new mental models and prototypes into The Wild, we are ready to observe once again the effect we have on reality. We record the new experience, so we can share it with our peers in The Pub.*

**Proceeding several times clock-wise through this learning journey (see**
***Figure 1***) reveals an iterative upward learning spiral that also allows for crossovers in other directions. We can imagine how The Pub serves as a meeting point for peers that come from both The Wild and The Attic, to compare their experiences with their mental models. This crossover in particular has proven valuable to Kolb when he found that "bringing together the immediate experiences of the trainees and the conceptual models of the staff in an open atmosphere where inputs from each perspective could challenge and stimulate the other, a learning environment occurred with remarkable vitality and creativity" [6].


*Figure 1. The model of the learning journey: The Wild, The Pub, The Attic and The Workplace*

The metaphors we used are open to interpretation. It should be noted that this learning journey does not intend to be a representation of Kolb's model, despite its resemblance. The workplace metaphor for instance goes beyond application of abstract concepts to the real world and incorporates the production of prototypes, products, services and even designed experiences. This stage, which is common in iterative design processes, seems to be missing in Kolb's definition of *active experimentation*.

## 3 APPROACH

Equipped with these metaphors we could now convey our approach to both students and staff. Through the use of the aforementioned story and the idea of a creative adventure, we opened up a dialogue about what kind of learning space would best facilitate the activities in each stage.

An interdisciplinary group of twenty-five art and design students enrolled for the elective course for undergraduate students. The course ran from the beginning of September to the end of October 2013. At the beginning, the students were provided with a completely empty classroom (i.e. demo space) of forty square meters, a budget of 1,000 Euros, a tutor (i.e. the "tour guide") and the learning journey model. We confronted them with the following question: “What constitutes an ideal learning space and what are the necessary accompanying house rules? Note the only legal constraints are that the space should be safe and hygienic.”

Facility management and their staff were banned from this demo space. As a consequence our safety or hygiene was to be assessed by ourselves and by consulting the fire brigade or hygiene inspectors. No preset rules were defined. Instead, we stimulated student to use common sense, and discuss what written and unwritten rules should apply in such a learning space.

The students' research, development and results were captured in their final presentations that include texts, images and video. The process of the course has been occasionally registered during class with video. The students' work and video footage was further analyzed to identify recurring themes and patterns.

## 4 RESULTS

### 4.1 Shared Vision

What resulted from the first discussion about the ideal learning space was a clear conflict of interests and goals. This conflict was amplified by miscommunication caused by incongruent jargon of different disciplines. After the initial controversy, we introduced the model of the learning journey to convey a general idea of what learning is about. Since metaphors are open to personal interpretation, all students easily recognized the four different stages. Regardless of their background or discipline, the model allowed them to describe and compare their individual and unique creative process and illuminate their experiences. The model turned into a tool that supported the development of a shared vision on the creative process, which in turn proved helpful in subdividing the idea of a learning space into more specialized types of learning space and their interrelatedness. We then formed groups, each one with a focus on one of the four metaphors.

### 4.2 Roadmap

In addition to using the learning journey as a mental map of the learning journey, we also used it as a roadmap for the design process, starting in The Wild. The students were asked to observe and register creative learning spaces "in the wild" (in and around the University campus). The twenty-five students were divided into groups of various sizes, which mean that some stages of the learning journey produced considerably more results than others. Each group selected a research method from the book "Universal Design Methods" [7]. This resulted in a wide array of types of registration, ranging from diaries, interviews, fly-on-the-wall observations, love letters and break up letters to photo studies and shadowing. Within popular types of learning spaces, like The Pub, different research activities yielded a rich diversity of aspects to consider. In addition, one workplace-group visited creative agencies to examine in what kind of spaces creative professionals usually work.

The next session was The Pub, where the students then shared their various observations of their chosen type of learning space. By sharing and comparing the results, we could now see similarities and differences between various types of learning spaces.

In The Attic phase, the students were asked to individually reflect on these results and find commonalities both within each type of learning space and across learning spaces. They were asked to present these findings to the group in a digital presentation format in the next session.
After that followed The Workplace stage in which students were asked to come up with plans or prototypes for their chosen part of the learning journey and showcase these in a final presentation. Since we only had forty square meters available, we unanimously agreed that The Pub team would turn our – still empty – space into an effective space for sharing and comparing. It also gave the students the opportunity to immediately test their ideas. The director of facilities management and two of her associates attended the final presentation as well.

### 4.3 Principles
The students have discovered some preliminary design principles for their selected types of learning space. They found that sharing in The Pub is ideal when sitting in a circular setup without tables. This setup maximizes a sense of equality and, as one student stated: "looking each other in the eye instead of watching fellow students' backs, makes one feel more pro-active while listening or discussing in class". Another principle they discovered is that objects that afford more than one type of usage, are preferable to single-use objects. Students also discovered the principle that it was healthier to sit in a chair that allowed for three different postures (normal, backwards and sideways) that keep the body in motion. Instead of an ergonomic chair that only allows for one passive posture.
Another outcome was what the students called the "Persistent Pen Principle". This started with the experiment of providing creative students with free materials to sketch, (e.g. paper and markers), which considerably increased the use of these. When they contemplated the possible stealing of these materials by students, they found that a constant resupply of these readily available materials resulted in a paradigm shift from owner to user, from "this pen is my property" to "I can use a pen whenever I feel the need to".

*Figure 2. Beanbags discourage the use of laptops and online chatting*

The most striking result was the "No Table No Laptop". Unintentionally, the use of a circular setup of lower seats and beanbags created a user experience that discouraged online chatting (see ***Figure 2***) that was previously made comfortable by use of a tabletop to keep a laptop in place. In addition, the circular setup also created an intimate sense of connectedness that – according to students – outweighed the temptation of social media. Students unanimously voted this circular low seat presentation space favourable over existing classrooms because of this increase in mutual attention.

### 4.4 Prototypes
A concept called "Your Own Box" was custom made at a local wine case producer. The idea behind it was to give every new student his or her own box to customize freely and use for any purpose, for instance sitting, storing, or building walls when combined with other students' boxes. A campfire setting was created with three-terraced height levels made out of customized chairs with tree trunk designs and beanbags. In addition students purchased candles with the scent of burning wood to enhance the "campfire" sensation of the space. This way, a setup consisting of self-made artefacts, repurposed objects and existing products resulted in the design of an environment for a new learning experience.

## 5 REFLECTION

For the director and staff members of facility management using the model was a valuable experiment, since they are in a transition phase with a shift of perspective from basic maintenance of facilities towards a more user centred value creation within the context they operate in. Reflecting on the process of our learning spaces experiment we noticed that their focus shifted from "managing facilities" to "facilitating learning", which they embraced as the vision for their future way of working.
Also the reflections of the students show how it changed their perspective on learning spaces and learning activities; as one of the students observed: "When I am in the canteen for example, I see how the configuration of space has an impact on how the space is being used. How it affects the dynamics. Now I see it everywhere." Apparently the model of the learning journey served as a new frame, stimulating students to take a new perspective on the situation: "We soon concluded that creating one ultimate space for all disciplines is impossible. I personally found this difficult, since I could not see how we could proceed beyond this point. How could our interdisciplinary team possibly collaborate on this? Fortunately Bruno provided us with a structure that completely changed our approach. The learning circle offered an entirely different perspective."

## 6 DISCUSSION

From our observations we can derive three key insights: (1) the reframed learning journey and its metaphors offer a tool to create a shared vision on learning spaces for various collaborating creative disciplines. Metaphors in particular serve as powerful frames that bridge communication and generate new understanding [8]. (2) The learning journey offers an effective roadmap for an iterative process that can be used for co-design of learning spaces. (3) An ongoing co-design process of learning spaces that *defines use through use* seems to imply a similar process of *defining rules through use*.
The process brought to light that this process enhances ownership of students. The students' final reflection documents show that they were surprised by the unexpected effect of space on their learning. Students stated that they would never be able to go back to being unaware of the impact of space on their activities. Also they described how the model of The Wild, The Pub, The Attic and The Workplace helps them to differentiate their various learning activities and the need to find the best suitable spaces for these activities.
It was the approach of *design through use* that offered unexpected additional benefits that we could not have imagined. This is most apparent in the current issue at the university that concerns the abundant use of social media in class. Had we followed a process of *design before use* it is unlikely we would have thought of the combination of using beanbags in a circular setup without tables to solve this.
This brings us to another interesting outcome. Coming up with "rules of the game" for new types of learning spaces benefits from first interacting with various demonstration space setups, before actually defining these rules. *Defining use through use* has the advantage of allowing for the emergence of behaviour principles. As opposed to a prescribed set of official rules that attempts to prevent every possible kind of abuse, the emergence of *rules through use* better suits an ever-changing learning environment. This minimizes restraints for learning and maximizing the possibility of rules becoming obsolete, since –as in the example of the beanbags – there is no need for rules to counter abuse in an environment that does not afford this abuse.

## 7 CONCLUSION

We started out with the question: how to facilitate a negotiation process in terms of developing a shared vision on learning spaces in design education? When considering the challenge to come up with the written and unwritten *rules of the game* for a new learning environment, we think that what we have learned is that it is not so much about coming up with a fixed set of rules that one can hang on the wall or publish online. We consider allowing users to *define use through use* assuming they will also *define rules through use*. Since we are developing ever-changing learning spaces with multi-affordance objects, the way students use these is constantly changing and therefore the rules keep changing as well. This means, as suggested in the introduction that conditions of use constantly have to be negotiated, for each group and situation. We suggest taking this into account in the next iteration and exploring if and how emerging rules, conventions, rituals and principles in this ongoing space-making process should be facilitated or stimulated. Some questions that for further research include:

how will other courses perform in this demo space that is continuously changing and where the house rules will be submitted to the ongoing negotiation between all parties that use the space? And how can teachers – as users – take part in this co-design process in such a way that they will not overrule or otherwise dominate the negotiation process?

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# HOW INTERACTIVE CAN A LECTURE BECOME?

**Mehran KOOHGILANI**
Faculty of Science & Technology, Bournemouth University

**ABSTRACT**
The uses of technology have been well documented and many people have tried to use the available technology. A pilot study has been implemented in order to facilitate the use of social media, portable devices, forums and the good old chalk and talk technique to bring the big lectures back to life. Improve the student experience and the learning by engaging everyone. The dynamic environment of the lectures would be enhanced by allowing interaction on all levels from delivery of the unit to questions and answers to setting and sitting examinations and assignments. Even the feedback mechanism would need to change. The research would require a huge shift in the way everything is done and the cultural consequences of the change may be more of effect towards the academics, especially ones with longer teaching experience.

*Keywords: Social media, interactivity, digital media, teaching methodology*

## 1 INTRODUCTION

It has been clear for a long time that the gap between schools (A Levels) and the university education is relatively large and sometimes it takes a lot of effort and support mechanisms in every institution to help student retention and progression, the so called added value. The issue of retention has been especially studied and researched by many colleagues in their respective universities. According to Meloni [1] it isn't a stretch to say that the definitions of "teaching online" and "teaching with technology" vary, even from instructor to instructor. "Teaching with technology" can mean using PowerPoint in a lecture, or the distribution of course materials via email, or customized course blogs enabling user-generated content, or the integration of wikified student-edited syllabi. Similarly, "teaching online" may mean an experience in which instructor and students communicate from disparate locations solely through a learning-management system such Blackboard or Moodle; a course in which the bulk of the content is delivered online but instructor and students occasionally meet face to face; or a regular face-to-face classroom experience supplemented by online discussion and accessible writing such as in student blogs. Whatever the level of technology, and regardless of our comfort level with it, remember that for all that educational technology can offer through new communication methods and the ability to reach a wider range of students, it is no panacea. An instructor must still deliver relevant material, enable students to achieve course goals, and assess their work. Students must still learn the material, use assignments and discussion opportunities to achieve course goals, and, ultimately, produce work to be assessed. However, if the student does not read, digest, analyse and interact with the lecture and the notes given, then the whole process will be wasted. Gow & Kember [2] attempted to discover whether parallel conceptions of teaching can be identified and, if so, whether they are related to student learning outcomes. Initial investigation was through semi-structured interviews with lecturers at a polytechnic. Constructs identified from the interview transcript were transformed into scales for a questionnaire. Different sets of polytechnic lecturers responded to trial and final versions of the questionnaire. Analysis of the final version of the questionnaire identified two main orientations to teaching — learning facilitation and knowledge transmission — made up of five and four subscales respectively. According to Mathias [3] Previous teaching models in the learning theory community have been batch models. That is, in these models the teacher has generated a single set of helpful examples to present to the learner. Hurson and Kavi [4] discuss the constant increase in the cost of higher education; recent market demands for computer specialists; lack of expertise in offering technology-oriented courses; and a new class of non-traditional adult students, combined with the constant pressure to maintain small class sizes call for new teaching practices. Furthermore, it has been proven than people's learning styles differ; most students absorb and retain visual material more readily than other types of material, but the world is full of ear-learners and those who learn by physical practice. The average learner retains about 20% of what is heard, 40% of what is seen and heard, and 75% of what is seen, heard, and experienced. A traditional classroom setting mainly offers seeing and hearing practices; print- or video-based distance study breaks the classroom boundary but offers the same teaching practices. Recent marriage between computation and communication technologies offers a natural solution to these issues: Advances in computer technology allow information to be presented in many different ways (multimedia); hence, interactive computer courses offer all three modes of learning. Advances in communication technology allow the information to be available anytime and anywhere. The marriage between the two allows a higher degree of accessibility and offers various learning modes beyond the traditional time and space limitations. Their paper addresses their effort and experience in developing a computer organization course using multimedia technology. The interactive nature of the lecture environment and the fluency of the data presented must be embraced by the student.

Stephenson [5] has looked at the developing understanding of approaches to online teaching and the emergence of pedagogies that will ensure online teaching and learning materials are effective. According to Ironside [6] the need to prepare students for a rapidly changing health care system sustains teachers' interest in developing students' thinking abilities at all levels of nursing education. Although significant effort has been directed toward developing efficient and effective strategies to teach thinking, this study explores the underlying assumptions embedded in any approach to teaching and learning and how these assumptions influence students' thinking. This study, using Heideggerian hermeneutics, explored how teachers and students experience enacting a new pedagogy, Narrative Pedagogy, and this article explains how enacting this pedagogy offers new possibilities for teaching and learning thinking. Two themes emerged from this analysis and are discussed: Thinking as Questioning: Preserving Perspectival Openness and Practicing Thinking: Preserving Fallibility and Uncertainty. According to Bronack et al [7] as the use of 3D immersive virtual worlds in higher education expands, it is important to examine which pedagogical approaches are most likely to bring about success. AET Zone, a 3D immersive virtual world in use for more than seven years, is one embodiment of pedagogical innovation that capitalizes on what virtual worlds have to offer to social aspects of teaching and learning. The authors have characterized this approach as Presence Pedagogy (P2), a way of teaching and learning that is grounded in social constructivist theory. In it, the concepts of presence, building a true community of practice, and constructing an online environment which fosters collaboration for reflective learning are paramount. Unlike learning communities that might emerge from a particular course taught under more traditional circumstances, students engaged in a P2 learning environment become members of a broader community of practice in which everyone in the community is a potential instructor, peer, expert, and novice—all of whom learn with and from one another. The student behaviour and expectations are rapidly changing, so much so that it has become very difficult to map or even cater for. A very long time was spent thinking and researching about various methods of learning and teaching. However, none really works. This maybe a dogmatic and cold hearted response but nonetheless is true. Academics including the author as well as psychologist have erred on the side of caution as well as the positive side of the teaching and engagement theory. It was decided to think outside the box and a completely blank canvas. The attitude needed to be bold and it was also necessary to observe and experiment. Any lecture could be bland and dry or become as fun and engaging as any by simply creating that rapport between the lecturer, students and topic. This paper aims to describe the somewhat novel and successful processes used in order to facilitate this through modern interactive tools, multitasking, as well as nurturing creative and analytical approaches. It has been built upon the technologies and processes that the students are already familiar with through their school years and taking it to the next level. It has allowed the students to influence the delivery and their interaction with it. Encouragement, technology and nurturing have been the main key indicators and the route to success. With the increasing fees and the changing landscape and climate of higher education, it has become difficult to fill the courses at universities. Therefore it has become even more imperative to make sure that once the students are enrolled onto the relevant courses, maximum student retention is maintained. Of course it must be emphasized that every course has a magic number of drop outs. It is assumed that the readers of this article also know that even in the days of free education and plentiful number of applicants, the reduction of wastage rates were always our duty and of great concern especially if it seemed to peak at any time. However, it has become more of an issue and concern nowadays with the advent of concept of student experience and student satisfaction surveys as well as the considerably increased fees. Numerous studies have been conducted over long periods on processes and circumstances by which student retention could be improved. This has prompted a review paper by the author of the studies of student retention techniques to be published in autumn. Suffice it to say that many articles and essays on the topic have been studied. Many of the models and suggestions have been implemented in the past with varying success. For Example Tinto [8] states that the dimensions and consequences of college student attrition and features of institutional action to deal with attrition are discussed. Patterns of student departure from individual colleges as opposed to permanent college withdrawal are addressed. After synthesizing the research on multiple causes of student leaving, a theory of student departure from college is presented based on the work of Emile Durkheim and Arnold Van Gennep. The theory proposes that student departure may serve as a barometer of the social and intellectual health of college life as much as of the students' experiences at the college. The quality of faculty-student interaction and the student's integration into the school are central factors in student attrition. Attention is directed to features of retention programs, including the time of college actions and variations in policy necessary for different types of students and colleges. It is suggested that effective retention lies in the college's commitment to students. The content, structure, and evaluation methods for assessment of student retention and departure are considered, along with the use of assessment information for developing effective retention programs. According to Cabrera and Nora and Castañeda [9] several theories have been advanced to explain the college persistence process but only two theories have provided a comprehensive framework on college departure decisions. These two theoretical frameworks are Tinto's [8, 10] Student Integration Model and Bean's [11, 12, 13, 14, 15, 16] Student Attrition Model. Cabrera et al [9] have validated Tinto's model across different types of institutions with differing student populations. In turn, the Student Attrition Model has also been proven to be valid in explaining student persistence behaviour at traditional institutions while modifications to the model have been incorporated to explain the persistence process among non-traditional students. Insofar as the two theories have attempted to explain the same phenomenon, no efforts have been made to examine the extent to which the two models can be merged to enhance our understanding of the process that affects students' decisions to remain in college. However, Cabrera, Castaineda, Nora, and Hengstler [17] have provided evidence that there is considerable overlap between the two theoretical frameworks. Taking these findings one step further, this study attempts to document the extent to which these two theories can be merged in explaining students' persistence decisions by simultaneously testing all non-overlapping propositions underlying both conceptual frameworks. Student retention has become a challenging problem for the academic community: therefore, effective measures for student retention must be implemented in order to increase the retention of qualified students at institutions of higher learning. Lau [18] suggests that institutional administrators, faculty and students play a vital role in improving student retention. For instance, institutional administrators can help students stay in school by providing them with the appropriate funding, academic support services and the availability of physical facilities, in addition to the effective management of multiculturalism and diversity on campus. Faculty members can help to maintain a positive teaming environment for students by using multimedia technology and innovative instructional techniques such as cooperative and collaborative learning in the classroom. Ultimately, the success of college retention depends on the students themselves. Therefore, students must be motivated to participate actively in their own learning process. Lenning [19] tried clarifying the various concepts of retention and attrition within a unifying conceptual framework, Co synthesize the research on retention and attrition, and examine the implications of the research for postsecondary administrators and researchers. Retention and attrition research pertains to both the percentages of students who complete programs and the reasons for completion or attrition. Practical considerations concerning attrition and retention that administrators should consider were briefly addressed. After clarifying terms, (including persisted activities, stopout, dropout, retention, and attrition), that appear to affect attrition and retention are described, and activities and strategies that may help reduce attrition rates are recommended. Theoretical and empirical literature was reviewed, as were attempts to classify retention. A new structure for classifying retention has been proposed, and indicators and measures for attrition and retention have been described. According to Wild and Ebbers [20] student retention is critical to the community college environment. They elucidate that in order to understand student retention issues in community colleges, it is necessary to identify the retention goal of the institution, the criteria, definitions, and data needed to monitor progress toward the retention goal. Only then can a retention program be designed and implemented. A plan to establish a college-wide retention program is included. They also provide an overview of past and present research pertaining to student retention. Reasons [21] has reviewed recent research related to the study of college student retention, specifically examining research related to individual student demographic characteristics. The increasing diversity of undergraduate college students requires a new, thorough examination of those student variables previously understood to predict retention. The retention literature focuses on research conducted after1990 and emphasizes the changing demographics in higher education. Research related to a relatively new variable—the merit-index—also was reviewed, revealing potentially promising, but currently mixed results. Here the aim was to wipe the slate clean and start with a fresh canvas. The authors wanted to think to use the jargon, outside the box.

## 2 METHODOLOY

After some soul searching, retrospective thinking and observations, it was decided to level the playing field, some might say move the goal post, and some might even say take our level to the student's level. The simple fact is that the new generation of students, whether supplied through student support or personally bought, are mainly reliant on tablets and smart phone. The technology has already been widely embraced by the student. The next step was have role models, course champions, someone whom then students could look up and warm to. Hence the PAL (Peer Assisted Learning) Project was resurrected. Mature students and higher level students were encouraged to nurture the weaker lower level students. Team working was widely and vehemently promoted. Regular meetings gathering were set up with links on the social media and forums. Live projects have run as competitions between the first and second year students. Cross framework design and engineering collaboration and competitions have been encouraged. BA students have been given the opportunities to contribute to BSc students and vice versa. Even the new BEng cohort were encouraged to contribute. Students have a studio days in which they are given a brief at 9 am and they need to come up with solutions and manufacturing plans by 5 pm. The sessions were initially run strictly through the project tutors but gradually they were put in charge up to the point where the academics acted as arbitrators. Sometime projects were resurrected in order to achieve optimization. Sometimes different levels and design groups where mixed. Guest clients from other courses within the school were used. The aim was to simulate the real world and promote growth and developments as well as time keeping and the professional etiquette. Ex-students in industry and students on placements have been called upon to help the freshers ride the initial turbulent tides of higher education. All this has to been done in the light of the balanced work load which to be honest is the most difficult challenge.

## 3 DISCUSSION

This is the generation student experience, and student surveys as well as the National Student Survey (NSS). This is a generation which has for major part has grown up being told what they need to pass the exam. This is the generation of student forums and the complaint culture. This is the generation of tell me what to read, give me enough notes; do not ask me to do any extra work as part of my learning if it is not assessed. This is the generation that would rather keep typing words into Google in search of the solution to a question set in the lecture. This is the generation that prefers not to read book unless it is full of glossy pictures and displayed on a high resolution screen. This is the generation who thinks of a library as this building full of old books but may have a nice trendy coffee shop just outside it. The authors appreciate that is an over generalization and as mentioned earlier there are exceptions to the rule. These comments and observations have not been made likely. Many hours of observations have given credence to these. A typical lecture theatre with a capacity for 250 students would at best be housing 100 to 110 students. These students would be scattered all over the hall. There will be pockets of student sitting together, some more densely packed than others. There are always the loners as well as many empty seats. The dense pockets usually tend to be at the back of theatre and the loners sitting at the edges on the front. The rest scattered all over the place. The salient fact is that there are many empty seats in between. This is still not a problem on its own, since students could be asked to move to front seats; however, the simple task of rearranging the class is time consuming and is more reasons for the students to not be satisfied. The issue becomes a problem when you realize the reason why they have chosen to stay away from lecturer, is simply because they want to enjoy using their smart devices for other activities other than the lecture. The other side of the argument is that at least they have made the effort of turning up to the lecture, the fact that they have chosen not to engage whilst they are in the lecture theatre is of prime concern to any lecturer especially if they enjoy their work. Students have been observed to even bypass the calculators on their mobile devices and have tried to use Google as a calculator. All these observations reinforced the need for the interactive teaching and utilization of the technology familiar to the current generation. In order to achieve what was set up, the system had to work seamlessly but the student body is many things but seamless. In many cases, it takes real courage and dedication on the part of the academics involved, to be complementary and encouraging. As academics, you understand the importance of this and hence it is done. Another challenge has always been that of how do you persuade industry to want to be involved with live projects. It is understandable that a company would look at the time involved and would ask the question what is in it for me? In these cases this barrier was traversed by selling the idea to the companies with argument that where else, would they have the opportunity to tap into so many young, vibrant, fresh and untapped minds? They could reap the benefits of new ideas and designs and concepts generated especially if they would set the design briefs. The incentives for the students came in the form of assessments, prizes and possibility of placement not to mention the opportunity of seeing their designs becoming commercial realities. Students could develop, test and submit their ideas and concepts online. Students were encouraged to twit about their ideas and then discuss their concepts on Facebook. Ultimately a Who Wants to be a Millionaire theme competition was run.

## 4 CONCLUSIONS

It is clear that the combinations of increased fees, the school mentality and the near addiction to their smart devices are all responsible for how the current student generation treats higher education. For many the work load and the expectations of the academics is far more than what they are prepared for or want to be committed to. It is interesting that even overseas students who may have had a more regimental schooling or have already been through an undergraduate course and are studying for masters degrees are no different. It would be interesting to know if they are affected by their classmates or is it simply that they are also addicted and distracted by their devices. The interactive process has proved successful and the full implication will become apparent once one full cohort has gone through. We are optimistic and all signs are positive. The approach proved to be a success for all parties involved from the student engagement and satisfaction to fulfilment of the company requirements. Above all also it has improved the student retention considerably. Of course it must be noted that many other factor have also contributed to the retention rates, namely correct screening of applicants in the first place during the open days and interviews. The dedication of the academics and admin has played a big role in the retention rate.

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# THE MINDCARD CONCEPT: INCREASING INTERACTION IN SMALL GROUP LEARNING SETTINGS

**Moritz MUSSGNUG, Stefan BOËS, Bastian LEUTENECKER, Dominik NOLI and Mirko MEBOLDT**
ETH Zurich, Switzerland

**ABSTRACT**
Learning and teaching in small groups of students with less than ten participants is a common setting in engineering design education at ETH Zurich. It can vary from class teaching and coaching sessions to study groups and project work. All learning settings usually include a platform like a whiteboard for the visualization of content and information exchange. To complement this visualization, we add magnetically attachable stiff cards (Mindcards) to the whiteboard figure of drawings and text. One can write and draw on Mindcards with common whiteboard markers. By enabling to shift the cards easily and freely, the Mindcard Concept allows to rearrange and modify the evolving whiteboard figure continuously without the effort for erasing and rewriting.
We introduce the Mindcard Concept as well as the respective physical tool and environment, and give three exemplary use cases for the concept: (1) modelling function structures, (2) structure trees, and (3) planning and organization activities. The study of teaching and learning settings for small groups of students lead to our major hypothesis: The Mindcard concept lowers the barriers of modifying and further developing whiteboard figures and this leads to increased interaction between the students and the teaching staff. Furthermore this induces an increased number of iterations of the overall whiteboard figure and also the acceleration of iteration cycles.

*Keywords: Design education, visualization, Mindcard Concept, learning setting, interaction, iteration*

## 1 INTRODUCTION

Interaction has been acknowledged early in educational research as one of the most important aspects of the learning experience [1]. The term interaction itself is used very often in education literature of all sorts [2] and is defined as "all manners of behaviour, in which individuals and groups act upon each other" [3]. This includes the essential characteristic of reciprocity in action and responses. In their work on the art of teaching, Simpson and Galbo [3] state that interaction not only enhances learning but is central to the learning process as well. In learning settings of small groups up to ten students, the frequent and intense interaction between the participants and the teaching staff is a great chance to enable a social dynamic and enrich the learning experience. Such settings usually include the use of some sort of visual support for presenting and exchanging knowledge. Visser [4] points out, that students need to be in continuous interaction with qualitative and imprecise visualizations to interact with their mental images. The requirement of visualization and continuous interaction with a qualitative representation is often fulfilled by a whiteboard, meaning a ferromagnetic surface that can be written on and the ink can be wiped away, making it reusable and modifiable.

The aim of this paper is to introduce a concept and a tool, both developed by the authors for complementing the work with whiteboards in teaching and learning environments of small groups in engineering design. All findings are deducted from qualitative observation of courses in the mechanical engineering education at ETH Zurich.

In the following, the different variations of learning settings with less than ten participants are described and classified. As a supplement of a visualization platform, in particular the whiteboard, the Mindcard Concept is introduced. First the physical properties and the concept of use are described, followed by three typical use cases for engineering design education. Finally the key success factors of the Mindcard Concept are named and analyzed.

## 2 LEARNING SETTINGS IN SMALL GROUPS

To get an overview of the learning settings in small groups, the different occurrences are characterized in the following. Based on that, a model for activation, the transition from one setting to another is purposed and described.

### 2.1 Classification of learning settings

This paragraph describes the typical sorts of learning settings for small groups of maximum ten people. Commonly, in learning settings in groups of this size, a visual support like a whiteboard to communicate content between people is used and becomes more and more a standard equipment for teaching facilities. It has the advantage of an intuitive handling and allows sharing content collaboratively by enabling multiple persons to input information simultaneously. A visual support like a whiteboard will be referred to as visualization platform. In the following, the four learning settings in small groups are described. Figure 1 visualizes all four settings with student and teacher, symbolized as empty and filled circle, and the dark bar representing the whiteboard.

- The *class teaching* describes the classical learning setting. A teacher is in front of the group and teaches the lectures content by the support of the visualization platform. This setting is characterized through a strong hierarchy between the teacher and the students.
- In a *coaching session* the teacher is more integrated in the group and acts like an expert. He has a leading function in the whole process but the creation of content is developed collaboratively.
- The *study group* is when the students have either received enough input to act without the teacher or have a different theoretical knowledge, which they can teach to each other. Here the teacher is in the background and intervenes only in situations of fundamental failure in the procedure.
- In the *project application,* students have the complete theoretical background they need and deepen their understanding of a certain method or tool by applying it to a specific task or problem. The teacher is not directly involved in the learning process, but can be contacted on the initiative of the students, if needed.

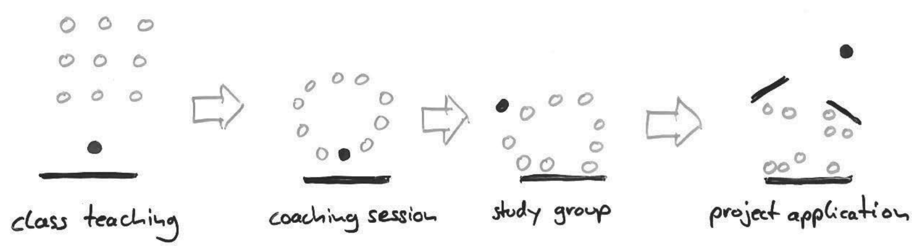


*Figure 1. Learning settings with small groups*

### 2.2 Activation process

In the application of the described learning settings both of the following patterns exist: a single setting can be constant over a whole lecture as well as the setting can be transformed within one lecture, once or multiple times. Typically, the transformation is performed from class teaching, to coaching session and study group to project application (in Figure 1 from left to right). The aim is to have a high level of interaction between the students, which deepens the understanding of a certain method or tool. The highest interaction rate is reached when learning in a student project. Hence we focus on reaching the right side of Figure 1 in the context of small group learning. The transformation from the left to the right learning setting we call "activation", as it activates the students towards more involvement and participation.

## 3 MINDCARD CONCEPT AND USE CASES

This section introduces the Mindcard Concept for teaching and learning in small groups of engineering design students. The central aim is to support interactivity in team processes. Furthermore the concept aims to support each of the described learning settings as well as the transformation from the mere class teaching method to a more interactive setting.

### 3.1 Physical properties

The Mindcard Concept is based on flat cards (Mindcards), which have the size of a third of an A4 format and are made out of polymethyl metacrylate (PMMA). The user can write on the Mindcards with standard whiteboard marker, and can clean them with a whiteboard wiper. Hence the surface can be re-written like a whiteboard surface. It can be easily written onto the card while holding it in the hands because of the stiff structure of the card. As illustrated in Figure 2 the card itself is equipped with two Neodyn magnets that allow the attachment to any ferromagnetic surface as whiteboards, blackboards or sheet metals. Hence the Mindcard acts like "a small whiteboard on the main whiteboard". The material of the card can be both colourful and transparent. This concludes in two effects. First, the colourfulness in combination with the cards plasticity and an acoustic click effect, caused by the magnets pulling the card tight when adding it to a whiteboard, creates high attention of the audience to the listener when using a Mindcard. Second, the transparency of the Mindcard allows visualizing contents in three layers: the surface of the whiteboard, the backside of the card and the front side of the card, which is directed to the user (see right side of Figure 2).


*Figure 2. Mindcards attached to a whiteboard*

### 3.2 Concept of use

The Mindcards are used on ferromagnetic visualization platforms, as whiteboards. To write on the card there are different possibilities: they can be placed horizontally on the table, they can be hold in the hand and they can be labelled already attached to the visualization platform. Once placed on the board the cards can be shifted and rearranged easily to create clusters or describe dependencies. In addition to that, the content written on the card can be added, changed, or erased during the usage. Hence both, the content that is written on the card and the position of the card on the platform can be modified, which allows evolving the content dynamically (see Figure 3 from left to right).

Furthermore, during the usage it is possible to remove cards, which are not relevant to the model any more, or should be attached to another platform. The transparent characteristic of the card gives an additional concept of use. A basic visualization that is fixed during the usage can be added to the back side of the card or onto the main board (for example a coordinate system or a defined basic shape of an electrical resistor). The variable content can be written on the front side (e.g. elements of the coordinate system or the values of the resistor). This allows changing the variable content, without erasing the basic visualization.


*Figure 3. Ideation process*

### 3.3 Use cases

The Mindcard Concept can be applied in different learning settings and for different contents and topics. In order to show the exemplary integration of Mindcards in design education the three following models are described below: user cases function structure, structure trees and state-gate model.

### 3.3.1 Function structure

A basic model in engineering design is a function structure as defined by Ropohl [5], where a collection of connected sub-functions represent the system as a whole. The functions are connected by the flows on which they operate. After a black box model with system input and output is created in implicit or explicit form, we start using the MindCards. On that basis function chains for each, in- and the output, are created to further aggregate them towards a functional model [6].
As an example shown in Figure 4, a coffee machine is modelled as the system of interest. The task on student's side is to model the function structure of a coffee machine and learn about the definition of a function, the notation of a function structure and the execution of a functional analysis.
During the process of modelling different behaviours between the use of a whiteboard with or without Mindcards were observed. First of all, the individual sub-functions can be collected on cards and put on the whiteboard. Compared to whiteboard without Mindcards, they do not have to be written down again in the correct position but instead can be moved around or replaced until the final order is achieved. Also the functional chains that were modelled after the collection of sub-functions could be moved around easily and connected among other function chains. The arrows and connections on the whiteboard are drawn at the later stage of this process but can be, wiped away and be redrawn easily.
The individual learning challenges were first of all formulating a function, then modelling a function structure according to the notation and finally the application of functional analysis and decomposition.

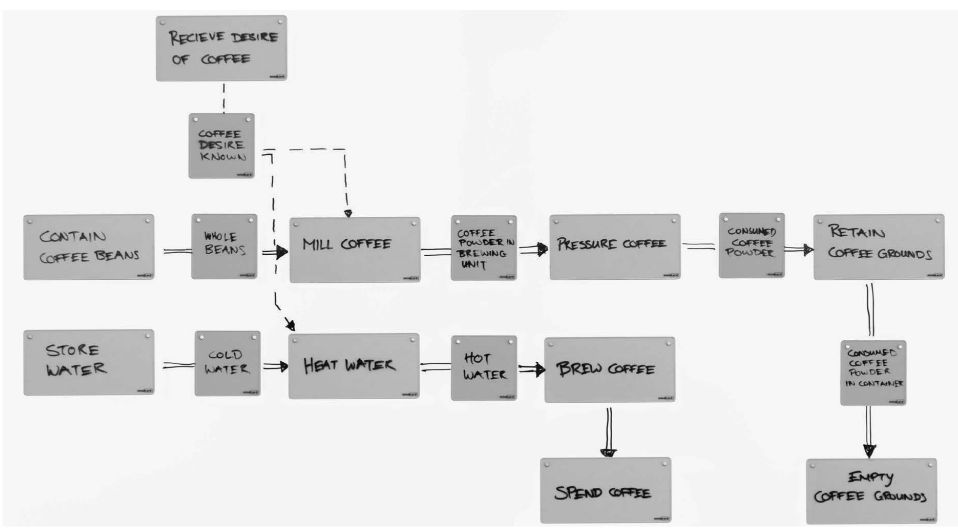


*Figure 4. Function structure*

### 3.3.2 Structure trees

For the task of showing hierarchical relations a structure tree is a very common visualization form in a variety of different applications. Some examples are fault tree analysis [7] or system decomposition [8]. The example used for this use case is a need hierarchy based on the need finding theories [9], which is important for deriving the underlying requirements of a person. It consists of the needs of a person on different levels of generality. Going up the hierarchy the "why" question is asked, going down the "how" question is focused upon.

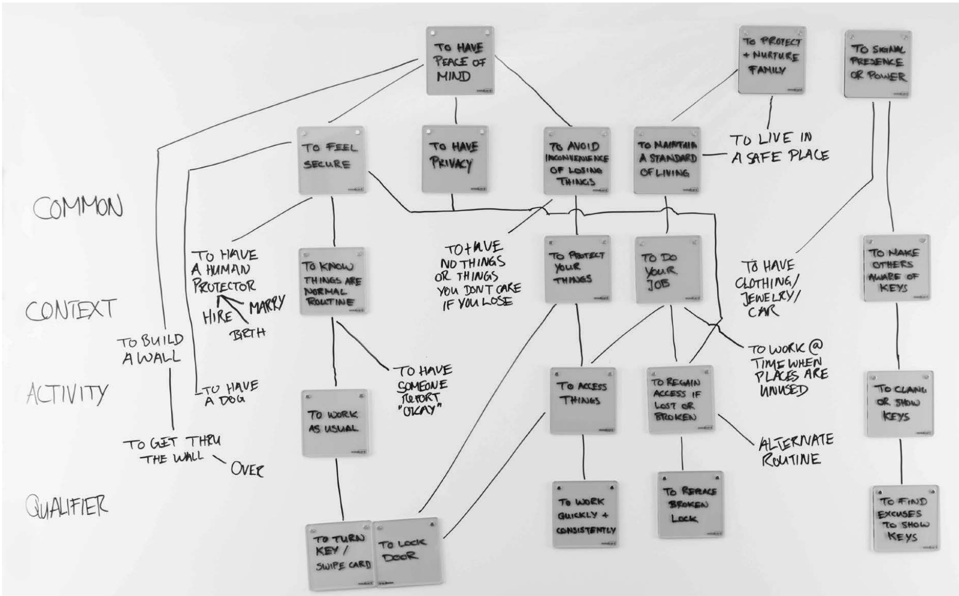


*Figure 5. Need hierarchy*

The task was to map the needs of a user utilizing a mechanical key and lock system. The results are shown in Figure 5. One Mindcard is used for one need, making it easy to collect them first and then put them into hierarchical order. The main learning effect, despite the concept of need hierarchies, is the application of the MECE rule: Create mutually exclusive (ME) entries on the same level and collectively exhaustive (CE) hierarchy branches.

### *3.3.3 Stage-gate-model*

Incorporating project-based learning in design education, project management topics form an important part of the curriculum, ideally by applying it in student projects. Often the stage-gate-model [10] is taught as a famous process model for product development. An important aspect is breaking down the development goal in smaller goals called gates that constitute the completion of the respective development stage.

This aspect shall be learned and internalized by the students. Therefore the task is to model the different stages, sub-stages and gates of a development project. This begins with brainstorming the gates and the content for each stage, bringing sub-stages into order and arranging everything along the time axis. A part of the results can be seen in Figure 6, where three stages are modelled.

A big benefit of the use of Mindcards is the option to move the whole stage around along the time axis without rewriting everything. New stages can easily be fit in between and existing stages can be detailed with new sub-stages.

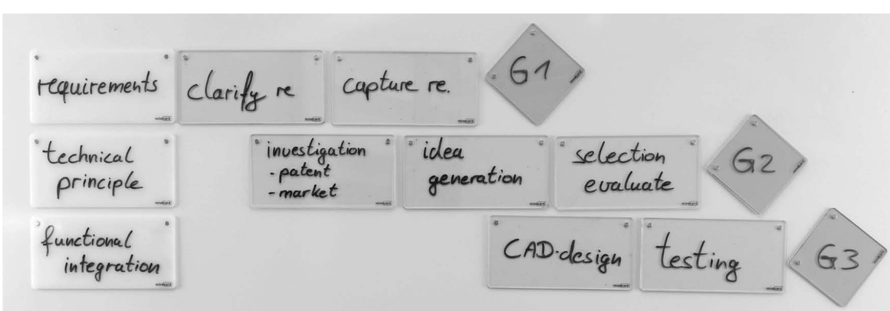


*Figure 6. Stage-gate-model*

## 4 INTERACTION AND ITERATION AS KEY SUCESS FACTORS

The Mindcard Concept was applied to small group learning settings at the Product Development Group Zürich in different lectures. The observations that have been made are subdivided into interaction, iteration and derived learning effects.

### 4.1 Interaction

Making use of the Mindcard Concept speeds up the activation process within a lecture, see Section 2.2. In our understanding this is caused by the flexibility of the created model. The cards allow bringing ones input to the visualization platform and update the current model easily. Hence, the barrier of modifying an existing model is smaller compared to conventional working styles on visualization platforms. The same reasons lead to the assumption that the interactivity rises by the implementation of the Mindcard Concept. Every participant can see that the current status of the model on the visualization platform is not fixed and one can bring in his ideas into that dynamic process.

### 4.2 Iterations

"Fail often to succeed sooner" is a famous phrase of Tom Kelly, the general manager of IDEO [11]. This philosophy does not only apply in the product development of companies but also in the teaching process of engineering design. When students apply a new method or try to shape the learning content they are very likely to make some mistakes during the first few tries. Looking at the process creating the final output it can be seen that the implementation of the Mindcard Concept leads to a high number of iterations on the way to the final result. The students use the high flexibility of the model and change it permanently by bringing in new input, by rearrange the existing content or by removing parts after agreeing with the other team members. High interactivity and a high number of iterations lead to creative ideas on solving a problem, which supports the learning effect as well because of the relevance of the results.

### 4.3 Learning effects

Regarding the results of group learning processes under the implementation of the Mindcard Concept, it can be found that the students are quicker in understanding and internalizing the learning content than without the use of Mindcards. This is attributed to the high attention given to the content by the students listening and watching. We assume that this is caused by physical appearance of the card, the method of use and the high interaction rate during the lectures. The usage of the Mindcard Concept enables the students to achieve a common understanding of a task and the problem. Additionally the collectively generated results are accepted and acknowledged by all participants. The high number of iterations led to an increased number of (sub)ideas and at the same time to a higher quality of the end result.

## 5 CONCLUSION

This paper introduces the Mindcard Concept as physical tool and a method of use in small group learning settings with visual support. The implementation of the Mindcard Concept supports each individual learning setting as well as the activation process, which is the transformation from one setting to a more interactive setting, based on three aspects. First, the use of Mindcards leads to an increasing attention towards the content by the students. This is caused by the plasticity, the colourfulness and the acoustic effect when adding a card on a whiteboard. Second, the Mindcard Concept supports the interactivity between teaching stuff and students, which is particularly beneficial for small group learning settings. The concept allows people to bring input by adding new cards or to change the actual content by repositioning the cards or modifying the written elements on the cards. Third, the usage of the Mindcard Concept results in an increasing number of iterations. The flexibility of the cards leads to a dynamic model evolving the content, which increases the number of (sub)ideas and the quality of the overall result.

## 6 OUTLOOK

As the reuse of content created with the Mindcard Concept is limited to the used visualization platform, further research will be put into developing an interface for digitalizing figures created with Mindcards, so that a software based reuse and transfer of content will be possible.

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# ON GROUPING STUDENTS AND WORK TOPIC CHOICE IN COURSES OF LEARNING BY PROJECTS

**Joaquim LLOVERAS**
Technical University of Catalonia (UPC)

**ABSTRACT**
Two surveys were conducted among students in engineering courses where final work had to be delivered in the form of projects to ascertain their views regarding work group formation and topic choice.
One survey was carried out in two courses at the end of the first semester of the 2013-14 academic year (December 2013), and the other in three courses at the beginning of the second semester (February 2014). The results of the two courses in the first semester, as well as results of the three courses in the second semester, were averaged. As the number of respondents in the first and second semesters was similar, the results of the two surveys were also averaged to obtain global views on the two issues. This is discussed in the discussion section.
The opinions expressed by the students can be used as a good starting point to motivate them positively. In this way, they become more engaged in the work and more committed to learning.
The students were also consulted on their willingness to do (somehow rewarded) projects inspired by university research work or proposed by companies, for information purposes only. The results are mentioned at the end of the paper.

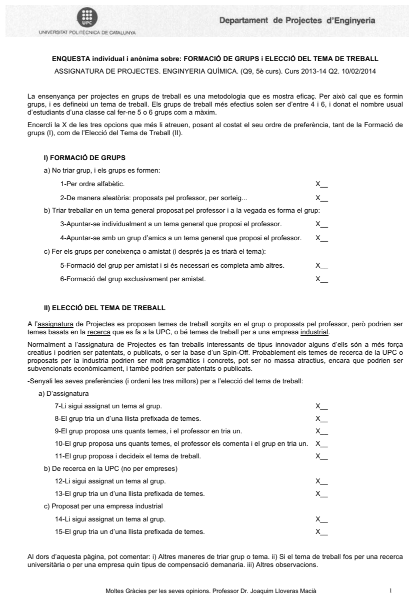
*Keywords: Work groups, topics, motivation, projects, surveys*

## 1 INTRODUCTION

Promoting positive student motivation engages students in their own learning will help them work with unnoticed effort and result in higher performance in learning course content. Content will focus on learning how to structure a project and develop an engineering design. Learning by projects in engineering design, involves different levels of accomplishment, i.e. project design and writing, project testing with modelling, or with a physical prototype.
To acquire knowledge, abilities and attitudes for project development, students are divided into work groups to discuss solutions and perform tasks. Several authors have analyzed various interesting aspects concerning of work groups [1-5]. In this paper, two important issues must be addressed before the start of the course to enhance student motivation: work group formation and project topic choice. Effective individual and group motivation significantly contributes to the accomplishment of learning objectives and, probably, production of good, original designs.
Although work group formation is generally previous to topic choice, both can occur simultaneously.
Several combinations were tested over time. This paper describes the last one, which is as follows: group formation is based on friendship, and if necessary the group is completed with other classmates; as for topic choice, the group proposes several topics, the lecturer comments on them, and then the group chooses one. On some rare occasions, the group proposes several topics, and the lecturer recommends only one.
In the 2013-14 academic year, students enrolled in two compulsory courses were consulted in these two issues through an individual anonymous survey given at the end of the first semester to measure the degree of acceptance of the above combination. The courses were Engineering Projects within the Chemical Engineering [6] and Industrial Engineering [7] degrees.
A similar survey was conducted with students enrolled in three other courses on the first day of class of the second semester to capture their preferences. The courses were Engineering Projects within the Chemical Engineering degree [6]; Product Engineering and Technical Systems I [8]; and Creativity, Ecodesign and Patents [9] within the Industrial Engineering degree. In this case, after a rapid count of the survey results, the most voted combination was applied in the three courses.

## 2 METHODOLOGY

The surveys comprised two main blocks of questions about group formation and project topic choice. They were given to the students at the end of the first semester (December 2013) and at the beginning of the second semester (February 2014). The questions in the two surveys were essentially the same, but the in the latter case they were in compact form (Figure 1) and the main points were enumerated consecutively. Moreover, students were required to rank the first three options in order of preference for each block.


UNIVERSITAT POLITÈCNICA DE CATALUNYA

Departament de Projectes d'Enginyeria

**ENQUESTA individual i anònima sobre: FORMACIÓ DE GRUPS i ELECCIÓ DEL TEMA DE TREBALL**

ASSIGNATURA DE PROJECTES. ENGINYERIA QUÍMICA. (Q9, 5è curs). Curs 2013-14 Q2. 10/02/2014

La ensenyança per projectes en grups de treball es una metodologia que es mostra eficaç. Per això cal que es formin grups, i es defineixi un tema de treball. Els grups de treball més efectius solen ser d'entre 4 i 6, i donat el nombre usual d'estudiants d'una classe cal fer-ne 5 o 6 grups com a màxim.

Encercli la X de les tres opcions que més li atreuen, posant al costat el seu ordre de preferència, tant de la Formació de grups (I), com de l'Elecció del Tema de Treball (II).

**I) FORMACIÓ DE GRUPS**

a) No triar grup, i els grups es formen:

1-Per ordre alfabètic. X__

2-De manera aleatòria: proposats pel professor, per sorteig... X__

b) Triar treballar en un tema general proposat pel professor i a la vegada es forma el grup:

3-Apuntar-se individualment a un tema general que proposi el professor. X__

4-Apuntar-se amb un grup d'amics a un tema general que proposi el professor. X__

c) Fer els grups per coneixença o amistat (i després ja es triarà el tema):

5-Formació del grup per amistat i si és necessari es completa amb altres. X__

6-Formació del grup exclusivament per amistat. X__

**II) ELECCIÓ DEL TEMA DE TREBALL**

A l'assignatura de Projectes es proposen temes de treball sorgits en el grup o proposats pel professor, però podrien ser temes basats en la recerca que es fa a la UPC, o bé temes de treball per a una empresa industrial.

Normalment a l'assignatura de Projectes es fan treballs interessants de tipus innovador alguns d'ells són a més força creatius i podrien ser patentats, o publicats, o ser la base d'un Spin-Off. Probablement els temes de recerca de la UPC o proposats per la industria podrien ser molt pragmàtics i concrets, pot ser no massa atractius, encara que podrien ser subvencionats econòmicament, i també podrien ser patentats o publicats.

-Senyali les seves preferències (i ordeni les tres millors) per a l'elecció del tema de treball:

a) D'assignatura

7-Li sigui assignat un tema al grup. X__

8-El grup tria un d'una llista prefixada de temes. X__

9-El grup proposa uns quants temes, i el professor en tria un. X__

10-El grup proposa uns quants temes, el professor els comenta i el grup en tria un. X__

11-El grup proposa i decideix el tema de treball. X__

b) De recerca en la UPC (no per empreses)

12-Li sigui assignat un tema al grup. X__

13-El grup tria un d'una llista prefixada de temes. X__

c) Proposat per una empresa industrial

14-Li sigui assignat un tema al grup. X__

15-El grup tria un d'una llista prefixada de temes. X__

Al dors d'aquesta pàgina, pot comentar: i) Altres maneres de triar grup o tema. ii) Si el tema de treball fos per una recerca universitària o per una empresa quin tipus de compensació demanaria. iii) Altres observacions.

Moltes Gràcies per les seves opinions. Professor Dr. Joaquim Lloveras Macià 1

*Figure 1. Survey in compact form about group formation and topic choice at the beginning of the second semester for three courses*

The following subsections are devoted to the several ways of creating work groups and selecting topics.

### 2.1 Ways of creating work groups

The first block consisted of three main options:

a) No freedom of choice for students. Groups formed by choosing students
   1- By alphabetical order.
   2- Randomly: as proposed by the lecturer, by drawing lots...
b) Groups are formed after students choose a topic from a list proposed by the lecturer. They can do it
   3- Individually.
   4- In groups of friends.
c) Groups are formed based on friendship:
   5- If necessary, groups are completed with other classmates.
   6- Based on friendship exclusively.

### 2.2 Ways of selecting topics

The second block consisted of nine options. Students may or may not participate in the choice of topics. These can be inspired by student ideas or arise from the lecturer's own proposals, a university research work or a company's proposal.

a) Topic inspired by students or lecturer:

1-A topic is assigned to the group.
2-The group selects from a list of predefined topics.
3-The group proposes several topics, and the lecturer chooses one.
4-The group proposes several topics, the lecturer comments on them, and the group chooses one.
5-The group proposes and chooses the topic.

b) Topic from a UPC research work
6-A topic is assigned to the group.
7-The group selects from a list of predefined topics.

c) Topic proposed by a company
8-A topic is assigned to the group.
9-The group selects from a list of predefined topics.

A note on the last page of the survey reads: On the back of this page, you can i) suggest other ways to choose group or topic; ii) specify the kind of compensation you would like to receive if the topic proposal came from a UPC research work or from a company, and iii) make other observations.
The results of the surveys are show in the next section.

## 3 RESULTS

The number of collected surveys per class was:

- At the end of the first semester: Engineering Projects (Industrial Engineering degree (IND)) 25, which accounts for 83,3% of the class; Engineering Projects (Chemical Engineering degree (CH)) 34, which accounts for 91,9% of the class.
- At the beginning of the second semester: Engineering Projects (Chemical Engineering degree (CH)) 19, i.e. 76% of the class; Product Engineering and Technical Systems I (P.EN) 17, i.e. 50% of the class; Creativity, Ecodesign and Patents (CEP) 19, i.e. 79,2% of the class.
- In the survey conducted at the beginning of the second semester (where the students' first three choices were ranked in order of preference), the weight associated with the first preference was 3 points, with the second 2 points and with the third 1 point.
- The final values for each question are expressed in percentages (Table 1) for the two courses at the end of the first semester and the three courses at the start of the second semester, with averages (Av.) for one and both semesters.

*Table 1. Percentage results for options for group formation of the 2013-14 academic year courses*

| | End 1st Semester | | | | Beginning 2nd Semester | | | |
|---|---|---|---|---|---|---|---|---|
| I) FORMATION OF GROUPS | CH. | IND | *Av.* | | CH. | P.EN | CEP | *Av* |
| 1-By alphabetical order. | 0 | 4 | *2* | | 7,1 | 1 | 2,7 | *3,6* |
| 2- Randomly: as proposed by the lecturer, by drawing lots... | 5,88 | 20 | *12,9* | | 4,4 | 6,3 | 13,5 | *8,1* |
| 3- Individual selection of a topic from a list. | 7,82 | 18,6 | *13,2* | | 3,5 | 8,3 | 22,5 | *11,4* |
| 4- Group of friends' selection of a topic from a list. | 31,85 | 1,3 | *16,6* | | 38,1 | 27,1 | 21,6 | *28,9* |
| 5- Group formation based on friendship, and if necessary completion with other classmates. | 53,41 | 54,6 | *54* | | 32,7 | 38,5 | 36 | *35,7* |
| 6- Group formation based on friendship exclusively. | 1 | 1,3 | *1,2* | | 14,2 | 18,8 | 3,6 | *12,2* |

These values are shown in graphic form in figure 2. The number of surveys collected at the end of the first semester and beginning of the second semester was similar, 59 and 55, respectively.
Option 5, namely group formation based on friendship, and if necessary completion with other classmates, was the best rated one in the group formation block, followed by option 4, namely group of friends' selection of a topic from a list, with half the points.

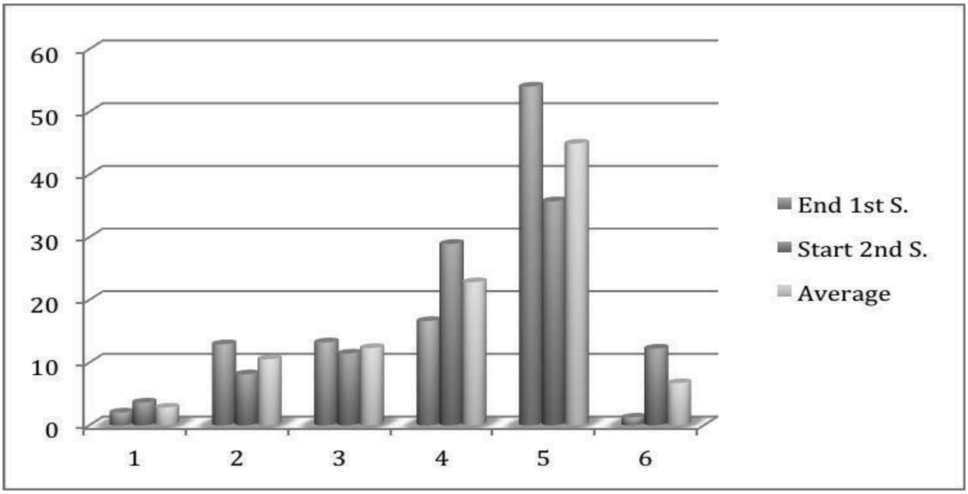



*Figure 2. Results of 6 questions about group formation (values in percentage). Left column: survey at the end of 1rst semester. Central column: at the beginning of 2nd semester. Right column: average*

The second block was formed by options for topic choice, with results shown in table 2. The values are similar for the two courses of the first semester; however, there is some dispersion in the answers given by respondents at the beginning of the second semester. On the other hand, the averages between semesters are comparable.

*Table 2. Percentage results for options for topic choice of the 2013-14 academic year courses*

| | End 1st Semester | | | | Beginning 2nd Semester | | | |
|---|---|---|---|---|---|---|---|---|
| II) ELECTION OF TOPIC OF WORK | CH. | IND | *Av.* | | CH. | P.EN | CEP | *Av.* |
| 1-A topic is assigned to the group | 0 | 1,9 | *1* | | 5,3 | 2,1 | 0 | *2,5* |
| 2-The group selects from a list of predefined topics | 12,4 | 7,5 | *10* | | 27,2 | 17,7 | 7,9 | *17,6* |
| 3-The group proposes several topics, and the lecturer chooses one | 5,7 | 9,4 | *7,6* | | 4,4 | 13,5 | 4,4 | *7,4* |
| 4-The group proposes several topics, the lecturer comments on them and the group chooses one | 17,5 | 18,9 | *18,2* | | 5,3 | 22,9 | 21,9 | *16,7* |
| 5- The group proposes several topics and chooses one | 6,8 | 3,8 | *5,3* | | 4,4 | 2,1 | 1,8 | *2,8* |
| 6- A topic from a UPC research work is assigned to the group | 0 | 1,9 | *1* | | 2,6 | 1 | 1,8 | *1,8* |
| 7- The group selects from a list of predefined topics from UPC research works | 26 | 24,5 | *25,2* | | 19,3 | 17,7 | 25,4 | *20,8* |
| 8- A topic proposed by a company is assigned to the group | 5,1 | 9,4 | 7,2 | | 5,3 | 0 | 0 | 1,8 |
| 9- The group selects from a list of predefined topics proposed by companies | 26,6 | 22,6 | 24,6 | | 26,3 | 22,9 | 36,8 | 28,7 |

The figure 3 shows these average results.

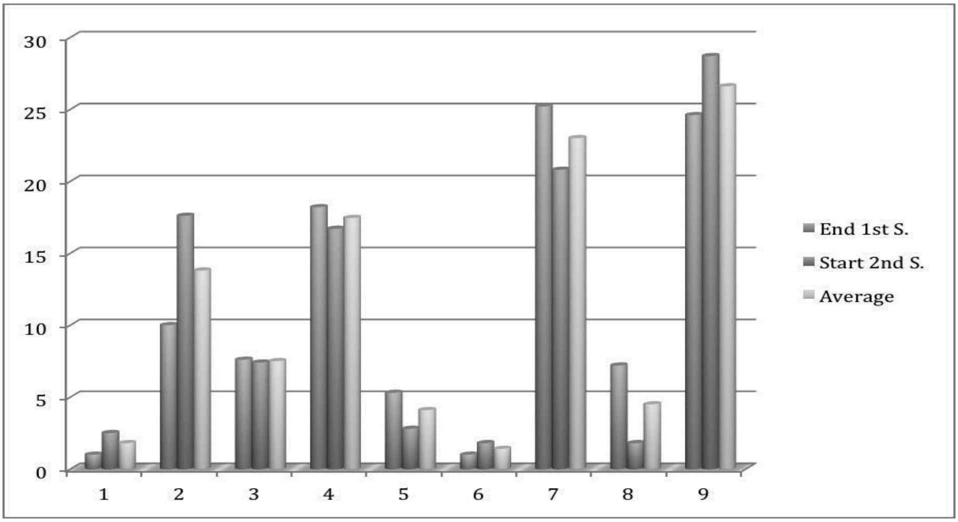



*Figure 3. Results for 6 options for topic choice (values in percentage). Left column: survey at the end of 1st semester. Central column: survey at the beginning of 2nd semester. Right column: average*

The best rated options are:

9: The group selects from a list of predefined topics proposed by companies (28.7%).

7:The group selects from a list of predefined topics from UPC research works (20.8%).

4: The group proposes several topics, the lecturer comments on them and the group chooses one (16.7%).

The results reveal a special interest in topics coming from UPC research works or proposed by companies. Unfortunately, these options are hypothetical because there is not organization to realize that, and the students' course works are not related to university research and companies' proposal. Notwithstanding, the lecturer was interested in knowing the students' opinions on this matter. Several papers deal with the analysis of the working relationship between industry and the university [10-11] in other countries.

Among the most voted, option 4 is the only possible one, and the results obtained at the end of the first semester confirm the preference for this option. However, option 2 was slightly more voted at the start of the second semester, especially in Engineering Projects (Chemical Engineering Degree (CH)). Therefore, this option was applied in this course.

Regarding the results for the open questions at the end of the page, it is observed that the question "If the topic came from a university research work or was proposed by a company, what kind of compensation would you like to receive?" was answered by few students; thus it is not very representative. However, a global trend in the answers to the three main questions is noteworthy: Would you accept without asking for anything in return? (with very few affirmative answers); Would you ask for your name to appear in a publication or a patent? (with nearly half the answers); Would you ask for an economic compensation? (with half the answers). Specifically, the interest in receiving an economic compensation is greater if the topic were proposed by a company.

## 4 DISCUSION AND CONCLUSIONS

Several combinations of solutions for group formation and work topic choice were used in the courses. At the end of the first semester, the total number of collected surveys was 59, which accounts for 87.6% of students, whereas at the beginning of the second semester only 55 students answered the questionnaire, i.e. 68.4% of students (perhaps because the registration process had not finished yet). As can be seen, the difference in the number of collected surveys is small.

The results for options for group formation confirm that the solution chosen for the courses at the end of the first semester as well the start of the second semester is the preferred one, namely group

formation based on friendship, and if necessary completion with other classmates. Option 4, i.e. group of friends' selection of a topic from a list, was ranked second.
With regard to topic choice, the survey results reveal a preference for option 9, i.e. the group selects from a list of predefined topics proposed by a company, followed by option 7, i.e. the group selects from a list of predefined topics coming from UPC research works. However, these options are not real; they are intended for information purposes. Option 4, the only realistic one, namely the group proposes several topics, the lecturer comments on them and the group chooses one, came next, which coincides with the lecturer's intuition about the students' preferences. It is also the preferred option at the beginning of the second semester, except by the students in the Eng. Projects course within the Chemical Eng. degree, who prefer option 2, i.e. the group selects from a list of predefined topics.
In summary, the combination between the most voted options for group formation and topic choice means that the students prefer to form groups based on friendship who, in realistic circumstances, propose several topics; these are commented on by the lecturer and then the group chooses one.
Although university project works can represent for students a creative phase of preparation for work in the industry, the survey results showed that, given the chance, students would prefer to choose a topic from a list proposed by a company and receive some sort of compensation which gives them visibility by appearing as authors on publications or as patent inventors. Alternatively, they would accept an economic compensation or a job offer. This issue about compensation requires further analysis work, and the relations between external research to university, and the topics of groups work of the Project course, could be an academic objective in our university.
Several combinations can be used for group formation and topic choice with the aim to achieve high student motivation and increase learning benefits. However, the choice of combination probably depends on the cultural context and circumstances.

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# DEMONSTRATION AND EVALUATION IN DESIGN: DEBATING THE USE OF THE MASTER-APPRENTICE MODEL IN VIRTUAL LEARNING ENVIRONMENTS

**Aysar GHASSAN, Cyriel DIELS and Alan BARRETT**
Coventry University

**ABSTRACT**
Rooted in face-to-face teaching, the 'top-down' master-apprentice model is the dominant pedagogical approach in design education. Through reflecting on the results from two case studies, we discuss possible advantages and limitations of extending the master-apprentice model to asynchronous Virtual Learning Environments (VLEs) with regards two overarching principles of design education—*demonstration* of skills and *evaluation* of the aesthetics of students' designs. This debate is important as universities are predicted to increase their use of VLEs. Case study one describes an online system through which practical skills are demonstrated to students via a 'master-apprentice style' approach. Learners' qualitative feedback suggests this method is beneficial. This infers that the master-apprentice method may aid tutors to *demonstrate* practical skills in VLEs. Case study two describes an empirical investigation in which a homogeneous group of design educators (i.e. design experts) evaluate the aesthetic qualities of transport designs. In identifying a low level of agreement, these results query research which argues that experts are capable of delivering objective evaluations in terms of aesthetics. The results of case study two question how successfully the master-apprentice model can be applied to *evaluate* aesthetics in VLEs as such environments can lack an opportunity for nuances in communication between tutors and students to be propagated. We conclude by arguing the results presented in this paper may be related to inherent differences between *demonstration* and *evaluation* in design. We call for research on how best these constructs may be negotiated in the design of future VLEs.

*Keywords: Design education, asynchronous communication, online tutorials, design evaluation*

## 1 INTRODUCTION

The master-apprentice model is synonymous with teaching in disciplines which require 'making'. It is argued [1: p.449] to be "perhaps the oldest form of education […] designed to provide training in the crafts and trades." The master-apprentice method is situated within a patriarchal social and economic model [1]; as such it is a 'top-down' model. In terms of product design education, its use can be traced back at least as far as the Staatliches Bauhaus. Characterising this system, the founder of this seminal institution, Walter Gropius [2: p.1], argues that the educator "instruct[s]" the novice. Gropius [2: p.3] affirms the patriarchal, top-down ethos of this model by stating that "the instruction of the individual is left to the discretion of each master". Much has changed since Gropius' era, however the master-apprentice system remains dominant in contemporary design education [3].

Research suggests the master-apprentice system enables tutors to demonstrate practical skills to students [4]. Indeed, students expect its use in this regard [4]. However, literature suggests its use in evaluating students' aesthetic treatment of form can be problematic. Frascara [5: 64] states:

*"I have seen instructors judge the quality of their students' work by saying: 'This one is too busy' or 'This is better, it is simpler.'* […And…] *that 'busy' is bad and 'simpler' is better in every situation."*

Because of the prevalence of the master-apprentice model, the predicted growth in use of Virtual Learning Environments (VLEs) by universities [6] means increased possibilities for design tutors to practice it in on-line settings. By definition, VLE conditions differ greatly from the face-to-face scenarios in which this teaching model is rooted. VLEs often primarily function through the creation of asynchronous communication between tutors and students [7]. Learners can have negative experiences of such phenomena [8]. Issues include isolation from a community of practice and technical problems [9] as well as the time taken for tutors to disseminate feedback [8]. Discussion on the potential benefits and disadvantages of the use of VLEs is particularly relevant to design education as research questions the value of extending the master-apprentice system to an online learning environment [4]. Through reflecting on the results from two case studies, this paper discusses possible advantages and limitations of extending the master-apprentice model to asynchronous VLE settings with regards two overarching principles of design education, *demonstration* of skills and *evaluation* of the aesthetics of students' designs [5].

## 2 CASE STUDIES

### 2.1 Case Study One: "Demonstration of skills via online Photoshop tutorials"

In transport design practice, Photoshop (PS) augments or sometimes replaces traditional manual visualisation processes. This case study describes a VLE developed by Author 3 in which PS skills are demonstrated to first year undergraduate transport design students via the master-apprentice system. In term one, tutors aim to develop students' manual sketching techniques. Tutors use the master-apprentice approach to demonstrate perspective drawing, effective utilisation of line weights and the principles of shading. In term two, PS demonstrations scaffold the teaching of practical skills. Author 3 uses a laptop connected to two large digital screens to demonstrate PS techniques and a graphics tablet to emphasise how PS can be used to create transport design sketches.

Two factors prompted these VLE innovations: growing student numbers and an increased body of international students whose mother tongue is not English. These issues limited Author 3's 'face-to-face' communication with the cohort. To support 'face-to-face' teaching of PS, Author 3 has created a series of web-enabled video tutorials in which PS skills are demonstrated to students. Screen capture programmes record both 'real time' screen activity during the demonstrations and associated spoken commentary. In this VLE, asynchronous discussions between Author 3 and students are constructed.

The first video in the series explains the PS interface layout, orientation and optimisation for sketching purposes (*Figure 1*). Subsequent videos convey basic PS sketching techniques tailored to allow students to transfer previously-gained manual sketching methods to a digital format (*Figure 2*). The videos build to form a library which students can access at any time.


*Figure 1. PS interface layout*

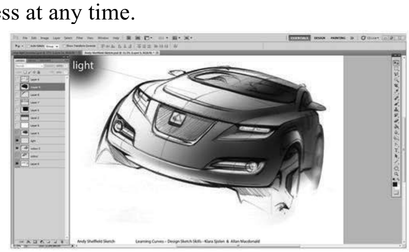


*Figure 2. PS shading techniques*

These recorded tutorials differ from other video tutorials available on Youtube.com or through other web 2.0 enabled channels, because they offer a structured and incremental approach to learning. The video library also includes examples of more advanced techniques, enabling more advanced students to find appropriate material, which, due to time constraints, cannot be covered in the 'face-to-face' demonstrations. The videos also maximise the value of 'face-to-face' demonstrations: the latter are recorded and edited for inclusion in the video library to capture both students' questions and Author 3's spoken guidance.

Videos are typically 15 minutes long and encourage students to practice the procedures shown whilst away from teaching sessions—for example when they are at home. Typically, each demonstration takes about 8 hours to prepare. The 'face-to-face' demonstrations usually last about 20 minutes, but can overrun if students wish to ask many questions. The larger the group the less questions are posed, which means that the videos gain in importance.

In terms of specific teaching and learning philosophy, prior to this trial, students applied a form of action learning, which is defined as follows: "a continuous process of learning and reflection, supported by colleagues, with an intention of getting things done" [10: p.11]. Via this method, students learn "with and from each other by working on real problems and reflecting on their own experiences" [10: p.11]. In terms of teaching PS, the action learning model proved not to be optimally effective, because in their eagerness to learn PS (or because of a lack of patience with the software), many students attempted to 'learn what they wanted to' rather than taking incremental steps. The latter is the best means to aid students develop their skills in preparation for professional practice. The PS teaching method is now in the form of blended learning, a combination of both traditional and e-learning activities [11]. This blended method of delivering PS tuition ensures sequential delivery to enable students to build skills and knowledge in an appropriate and cumulative way. The video library functions as a "digital learning object that can be reused to help facilitate and support learning activities" [12]. Returning to the study's aims, first year students were asked to provide qualitative feedback on the video library. A total of learners kindly provided feedback. These individuals were aged between 19 and 24 years; 5 were female, the remainder male. Their nationalities were: British, Chinese, Columbian, Korean, and Nigerian. Students noted negative issues linked to massification, for example:

*"getting everyone to be quiet during the tutorials"*

*"I personally could not pay attention because of the dark and the heat from the crowded classroom made me sleepy".*

Learners' feedback suggests the videos had helped students negotiate massification-related issues. For example:

*"the screen is a little small, maybe sometimes some mates can not see clear. Fortunately we have replay videos can be watch. It is very good."*

Also, feedback from separate students whose mother tongue is not English suggests the videos aided their understanding:

"*Replay is very important for me because I need to focus on both hearing and watching and I sometimes miss either of them"*

*"sometimes in class it is hard to understand what they are saying so the videos help me to go back if I don't understand something"*

*"The processes are clear, but some commentary I cannot understand. Most time I just analyze how do you do by Photoshop in the video".*

In summary, case study one suggests that the asynchronous communication intrinsic to the aforementioned PS VLEs can enable students to engage in effective distance learning.

### 2.2 Case Study Two: "Evaluation of aesthetics—inter-individual variability between experts"

Here, Author 2 asked a homogenous group of design experts (all transport design educators) to rate a range of compact urban vehicle concepts with regard to their aesthetic appeal and the extent to which each incorporated a range of aesthetic design principles. The participants were considered automotive design experts because they all worked as professional car designers for a minimum of 3 years previous to their current roles as automotive design educators and academics. The group consisted of males with a mean age of 46 years. Using a dedicated usability lab, the designs were shown on a 23" wide screen TFT monitor with the images subtending a horizontal and vertical angle of 13 and 7.5 degrees of visual arc, respectively. The vehicles consisted of compact urban concept vehicles and were chosen to control for difference in vehicle type and size and focus on the aesthetic differences within this specific category. Each vehicle design was shown in a three-quarter perspective and in greyscale to control for any possible effect of colour on participants' appreciation of aesthetics.

Using 7-point Likert scales, the participants evaluated the concept vehicles according to their aesthetic appeal and 8 design principles thought to be associated with automotive beauty. These principles were: 'simple', 'elegant', 'well-proportioned', 'flowing', 'sculptural', 'minimalistic', 'fluid', and 'understated' [13].

The level of agreement was operationalised as the Intraclass Correlation Coefficient (ICC) which is a statistical measure of the consistency with which the participants rate a given trait. The ICC takes on a value between 0 and 1 where the former indicates the absence of any consistency, and a value of 1 when there is perfect agreement. In the field of art, ICC values for criteria such as simplicity, coherence, and craftsmanship, tend to hover between 0.1 and 0.3 suggesting very low levels of agreement [14]. Given the homogeneity of the expert group, as well as the use of everyday objects (i.e.

cars) which show only limited artistic variation when compared to artworks, the authors hypothesised considerably higher levels of agreement within this expert group [14]. As shown in *Figure 3*, however, large inter-individual differences were observed as indicated by low ICC values.

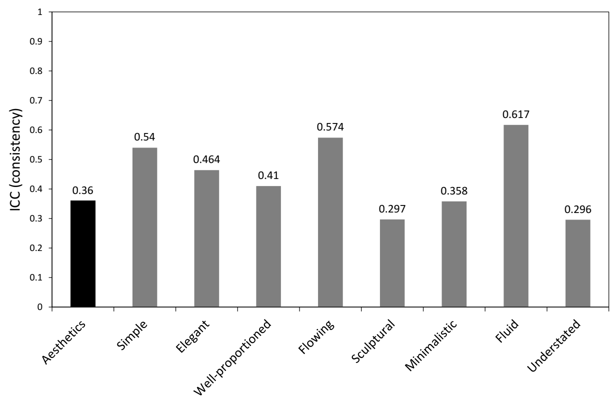


*Figure 3. Intraclass Correlation Coefficients (ICC) for aesthetic ratings and aesthetic design principles*

As the participants shared both a common education and experience as transport designers prior to beginning their careers as educators, they can be said to be *appropriate judges* [15] of aesthetics in their field. Such judges are considered to be capable of achieving high levels of agreement [see, 14]. Consequently, they are argued to be able to make objective decisions about aesthetics and associated design principles [15]. The large inter-individual differences identified here appear to be at odds with the above notions. This lack of agreement is particularly striking given that the principles were derived from a large body of domain knowledge existing of published automotive literature, surveys, focus groups and interviews with automotive design experts [13].

## 3 DISCUSSION

Case study one has described a method in which VLE-enabled master-apprentice style teaching of PS supports 'face-to-face' teaching of this software. This VLE functions via constructing asynchronous communications. This study has demonstrated that VLE (and accordingly distance-enabled) teaching of PS can successfully extend the reach of the master-apprentice model beyond 'face-to-face' scenarios. The results of this study appear to query aforementioned research [4] which questions the value of the master-apprentice system in VLE-enabled distance learning environments.

Case study two has described an investigation into experts' evaluation of the aesthetics of design concepts. It identified considerable disagreement amongst experts and thus called into question the notion that relevant tutors can achieve high levels of agreement with regards to aesthetics and associated design principles [see, 14] and can therefore make objective decisions about aesthetics [15]. The results of case study two raise the possibility that the evaluation of a design may not be fully captured through the use of commonly utilised terms within a particular design community. It can be argued that the 8 aesthetic principles used in this study may only refer to the most apparent and, cognitively, most readily available design principles. If this were the case, it may be at the cost of other, less prominent and less accessible design principles argued to be associated with aesthetic appraisal, for example the principle of 'prototypicality' [see, 16]. Whereas design tutors may not be consciously aware or be able to explicitly express the above, 'face-to-face' dialogue with students may allow for a more refined and richer design evaluation. 'Face-to-face' dialogue allows humans to pick up on nuances in communication and facilitates it [17]. Virtual communication channels can create communication problems between humans. Issues with communication via VLEs are exacerbated through participants' reliance on text to construct dialogue [18]. The potential to create poor communication increases when tutors construct asynchronous discussion via VLEs [7]. With the above in mind, it is possible that a tutor's 'top-down' master-apprentice style evaluation of design aesthetics [5] presented as a virtual asynchronous written dialogue may increase the chances of precipitating miscommunication with students. The results of case study two suggest that this situation may become exacerbated when evaluation of the aesthetics of students' designs is provided by more than one tutor via a VLE. A comprehensive search has not yielded literature discussing the effect on students of being presented with tutors' differing evaluations on the aesthetics of their designs. Perhaps this may be because the idea that experts are capable of making objective decisions [15] is widely accepted in design teaching environments? A lack of agreement with regards to individual tutors' evaluations may result in frustration for students and may prompt learners to request further clarification from their instructors. As noted, the time taken for students to receive responses from a tutor is one reason argued to exacerbate frustrations with VLEs [8]. Waiting for virtual responses from more than one tutor could further amplify these feelings.

## 4 CONLCUSION

As the prevalence of university teaching via VLEs is predicted to grow, it is important to debate how this may affect design education. This paper has aimed to stimulate such discussion.

We have argued that, with regards the teaching of PS, asynchronous communications constructed through a VLE have benefitted students' learning experiences with respect to issues related to massification and problems Accordingly, these findings suggest it is possible to extend master-apprentice demonstrations to a VLE format.faced by overseas students whose mother tongue is not English. The PS VLE was constructed to augment 'face-to-face' teaching. Further research will have to be conducted to evaluate whether VLE teaching of PS can effectively replace 'face-to-face' methods. This raises ethical questions on how such a study may be attempted: it is, for example ethically unviable for a group of students within a cohort to be excluded from 'face-to-face' demonstrations for research purposes. The results of case study two question research which argues that experts are capable of making objective evaluations of aesthetic values. Taken together with issues limiting communication via VLEs, these results suggest evaluating aesthetics via asynchronous dialogue may cause frustration for students.

The discussion in this paper appears to revolve around inherent differences between *demonstration* and *evaluation* in design. Arguably, the 'top-down' demonstration of PS skills is a 'more objective' practice as it involves explaining tools and illustrating the rational practice of shading form utilizing a light source (see, *Figures* 1 & 2). PS skills may therefore be more suited to being taught through asynchronous communication methods. Evaluation of students' aesthetic treatment of form, though performed in a 'top-down' fashion, may be a 'less objective' practice. We call for research on how the 'more objective' notion of demonstration and the 'less objective' idea of evaluation may be negotiated in the design of future VLEs. We argue this research may be important in benefitting students' learning experience in the digital age.

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# PERSONALIZING OUR APPROACH TO DESIGN

**Jennifer Liane SIGGARD, Tressa Ellen FURNER, Cecily SUMSION[1] and David MORGAN[2]**
[1]Industrial Design Students, Brigham Young University, Provo Utah
[2]Industrial Design Professor, Brigham Young University, Provo Utah

**ABSTRACT**
Our Industrial Design program is predominantly male. As women, we compared our performance and methods to those of our male classmates'. In our eyes, we lacked something that we could not pinpoint. We thought this was just a personal problem to "get over."
During the research for a recent project, we had the opportunity to work in an environment conducive to developing our own design approach. This proved to be the turning point in our self-concept as designers. We found that our so-called "problem" was not a problem, but an innate difference that needed to be treated as that: a difference.
We had been conditioned to look for successful people and emulate their specific method of achieving success. As our program is predominantly male, that is who we assumed we should emulate. We realized that our pattern of success did not need to exactly follow our male counterparts', but rather we should develop our own approach. This approach included:

- greater emphasis on team cohesion
- group problem-solving discussions
- focusing on end-user needs earlier in the process
- empathy driven research

While our approach is unique to us, this is not necessarily about us being female. We had these experiences while working on an all-female team, but learning to develop a personal design approach can be helpful to design students. Our findings are valuable because approaching design in your own way is not a problem to be solved but rather a difference to be discovered and capitalized upon.

*Keywords: Design approach, discovery, personalization, creativity in design education, learning spaces*

## 1 INTRODUCTION

We understand that this may not be a typical academic paper, however we are confident that our experiences and findings will enhance the way design educators teach as well as the experiences of our fellow students of design. We believe that all designers should have the opportunity to be successful. This success comes from personal victories as well as public acknowledgment of their design work. The goal of this paper is not to discredit current teaching methodology, but instead encourage designers--both students and design educators--to find and define their method of achieving success. Please keep that in mind as we share our experiences.

## 2 PERSONALISING OUR APPROACH

The Industrial Design program that we participate in is predominantly male. In previous years the program has had a lot more male students than female students. Even all of the professors of our program are male. Our specific class has 5 females and 12 males, which interestingly, is the largest number of females to be accepted into a class to date. The program that we are a part of is also highly competitive as few people who apply are accepted each year. Most classes are structured in a way that grading is on a ranking system where students are compared against each other. This ranking system naturally sets peers against each other and can often create unfavourable results in the dynamic of the class. This includes the rapport between professors and students.

Due to this competitive nature, we felt a need early-on to compare our performance and methods to our classmates. As time passed within the program, we (the five females in the class) began to feel that our performance and methods lacked something that we could not pinpoint. Even though we were receiving acceptable ranks, we were often dissatisfied with our work and our end projects. The representation of our work (where we were ranked) was not accurately connected to our accumulative performance in our minds. We began to notice that we often attempted to mimic the design methods and ideology of our male counterparts. We were spending more time and energy focusing on getting a 'good ranking' rather than focusing on developing a design method that worked for each of us individually. This left us feeling frustrated not only with our end designs, but also with the process used to get there. We felt that as females, we just had a personal problem to "get over" in order to better fit the mould that we saw our professors responding well to. This is a common pressure within the American culture. Historically, women have received success and recognition by complying with the traditional male standards in the workplace. None of us realized that our personal development as designers was being hindered by our perception that in order to achieve success we needed to act *exactly* like our male counterparts.

During the research for a project in our third year, we discovered an opportunity to design specifically for women as an all-female design team. This gave us the freedom to work in an environment conducive to our natural thinking, communication, and design methods. We began to work differently than we had in the past. Our quality of work improved and we were more efficient in our methods. We became much more satisfied with our designs and our process. This project truly proved to be the turning point in our self-concept as designers. We found that the so-called "problem" we thought we had was not a problem, but an innate difference that could be treated as that: a difference.

## 3 DEVELOPING OUR APPROACH

In this new situation, we discovered that success is individual, and methods for achieving success should be developed as an individual. Through our experience and research we have learned that individual patterns of success are not meant to be emulated exactly, but rather used as guidance to create our own path. This allowed us to develop our own approach to design, and in turn, our own approach to success.

Below are some behaviours and experiences that were instrumental in the development of our approach.

### 3.1 Greater Emphasis on Team Cohesion

As a team, we quickly developed a dynamic that allowed us to rely on each other's strengths. We were all equal partners and acted as a support system. Each of us was technically working on our own specific product, but the more we worked together each product became a conglomerate of all of our ideas and suggestions. Studies have shown that males use communication to establish and increase their social status. Females, on the other hand, use communication to create relationships and establish equality with their peers [1]. This was certainly true for our team and the work that we were producing. Before jumping into work, we would always check-in with each other, making sure everything was going well on a personal level. This was a different experience when compared to working with our male counterparts because the overall feel of the team was much less competitive and much more cohesive. This did not mean we agreed on everything, but it allowed disagreements to be discussed without contention or hierarchy. Though we were working in a completely different manner, our quality of work was comparable to our male counterparts.

### 3.2 Problem Solving Discussions as a Group

When compared to the all-male teams, our team more frequently discussed projects as a group. This behaviour is supported by research that shows that females tend to problem solve as a group, whereas men problem solve individually [2]. This is also validated by research about gender differences in conversation style [3]. We noticed that the males in our class worked predominantly as individuals, rarely talking to each other at all. On the other hand, all five of the females in our class sat together in a self-designated corner and had a discussion lasting the entire class period, and often longer.

At these weekly meetings, we would sit and discuss events in the past week that were not necessarily related to design. We would share ideas, new insights, and our progress for both our design work and in our personal lives. We would also share the design problems we had come across. Many times we were not seeking to solve them, but to share them with our team to reach a greater understanding. Research shows that females tend to view problem solving as a way to deepen or strengthen relationships whereas males view it as a way to demonstrate their competence or strength of resolve [4]. This was evident in our team compared to the male teams. While the males tried to solve all problems brought to the table, we were more apt to share our problems, discuss them, and then decide which ones actually needed to be solved and which ones were irrelevant. By talking things out, we were able to clear our minds and feel refreshed to continue again. This may be because females have a greater ability to focus on more than one problem at a time [5]. There were times when there would be ten different ideas being discussed, and it was only by discussing the ideas that eventually they would clarify and sort themselves out.

This propensity to problem solve as a group, and our ability to multi-task were important discoveries in understanding our previous dissatisfaction during our first couple of years in the Industrial Design program. While our male classmates were able to focus solely on their project, we would only be able to focus for a short time before all the other things on our minds would cloud our design process. During this project we realized that as females, we were more successful at problem solving when we did so as a group. This was a key aspect of our successes during this project. While we are currently working individually on various design projects, we still find it useful to regroup, talk over our thoughts, and get feedback on our projects. It has become a part of our personal approaches to design, and we have been more successful after discovering it.

### 3.3 Focusing on End User Needs Earlier in the Process

According to Smart Design's Femme Den, a highly successful design firm focusing on female consumers, women buy or influence up to 85% of purchases in the United States [6]. We are a part of that demographic and therefore are in a unique position to understand the consumer side of design. It is because of our unique position as females, that we saw the need to build a strong emphasis on end user needs. We have found that the best way to do this is to develop a persona early in the design process. Knowing that females typically have an easier time getting to know and understand people [7], our all-female team was able to quickly develop and gain a relationship with our chosen persona. Because of a strong relationship with our persona, we were able to gather more useful information than our male counterparts could, and therefore design a product better tailored to our end user. While our persona was created early in the process that did not stop us from refining it as we gained new insights. This helped immensely in the design process because we were able to essentially ask questions of our end user, and have them answered because the persona was so complete.

### 3.4 Empathy Driven Research

As an all-female design team focused on designing for a female end-user, we had the opportunity to experience first-hand a project where empathy drove our research. While researching, we found that we could relate on many levels to the things women needed and wanted in the end product. We understood where they were coming from and began looking for pain points that all parties needed solved. We were no longer designing for a persona, but rather a friend. That changed the way we did things and we gained a more urgent desire to create functional and beautiful products. By bringing ourselves into the design process--really understanding the worries, concerns, hopes, and desires of our end user--we found new successes and more satisfaction with the end products we designed. We believed more in our products, and as a result believed more in our unique design process.

## 4 CONCLUSION

We want to be clear: we are not proposing that males and females never work together. We are also not arguing that gender-diverse teams are inherently bad. Our intent is to emphasize that by being in an environment where we felt comfortable and more fully connected to our teammates; our approach to design was enhanced. We also noticed that we were more focused on design, rather than on our ranking. For us, this was working on an all-female team. We had innate similarities with our female teammates, allowing us to understand each other more fully, which then had an effect on our process. This team enabled us to more fully rely on each others strengths, learn in a more natural way from each other, and in the end, produce better and more satisfying work than we had in previous projects. This all-female team allowed us to feel confident enough discover who we are as designers instead of constantly trying to fit a specific mould. We came to understand that designing differently from our male counterparts was not a problem. It was just a difference that, by understanding, we were able to capitalize upon.

We would like to challenge design educators to not only allow your students to discover their own approach, but to encourage it. Do not assume that one specific method is right for all students. If at all possible, place more emphasis on design methods and approach, rather than an official ranking. And finally, we would like to challenge our fellow students to embrace the opportunities that lead you to discover your specific approach to design and allow you to achieve your individual success. If you feel that you have a so-called "problem", remember that innate differences can often lead to great opportunities.

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# IMPROVING ENGINEERING EDUCATION THROUGH DISTRIBUTED DEVELOPMENT PROJECTS

**Joachim LANGENBACH[1], Arne DEITERS[2], Amy HORTOP[3], Roland LACHMAYER[2], Armin LOHRENGEL[1] and Thomas VIETOR[3]**
[1]Technische Universität Clausthal, Germany
[2]Leibniz Universität Hannover, Germany
[3]Technische Universität Braunschweig, Germany

**ABSTRACT**
Employers find that students are graduating from engineering programs without the necessary competence and know-how to be successful in industry, often lacking sufficient communication and collaboration skills imperative for developing new products. Modern product development, from development and design through to production, planning, and marketing is moving increasingly to the digital domain as a result of technological progress and increasing pressure to deliver more complex and more customized products in less time at the lowest cost. The engineers of tomorrow must be able to communicate and collaborate effectively and efficiently using technologies and software, such as Computer-Aided Design (CAD) or Engineering (CAE), Product Data Management (PDM) or Enterprise resource planning (ERP) tools.
In an effort to ensure that graduating students can successfully apply what they have learned in their engineering lectures to real-world engineering problems, the Lower Saxony Institutes of Technology (NTH) has sponsored a project "Computer-aided Product Development" that involves students in distributed development design projects that mirror what they will come across in industry. Engineering students from the Leibniz University of Hannover (Institut für Produktentwicklung und Gerätebau), the Technical University of Clausthal (Institut für Maschinenwesen), and the Technical University of Braunschweig (Institut für Konstruktionstechnik) work together on semester-long projects that require them to use engineering tools that are not often taught in typical engineering classes but crucial for product development in industry, exposing current shortcomings in the engineering curriculum. The project has been run twice, once with "closed" student groups at each site, each group responsible for a sub-assembly and communicating with students at other locations with regard to sub-assembly interfaces, and a second time with students from multiple locations making up "mixed" teams. Competence weaknesses have been identified, particularly in using PDM systems, and measures to improve the curriculum long term are being integrated into lectures. This paper will provide an analysis of the first projects as well as prospects for improving engineering education through distributed development projects.

*Keywords: Distributed development, PDM, CAD*

## 1 INTRODUCTION

In increasingly competitive global markets, companies looking for ways to shorten product development time have turned to distributed product development. The availability of collaboration software and other tools has made it easier for employees to work together and yet be distributed around the world [1]. This becomes a challenge to educate engineering students to be adequately prepared for development occurring mostly in the virtual realm. Employers find that students are lacking the desired competences upon graduation. In an effort to better prepare student for industry, collaboration between NTH schools examined methods and tools of Cross-Enterprise engineering (CEE) along with particular student competencies. The goal of the NTH Project is for students to gain experience in a distributed development environment of CEE while giving instructional staff an opportunity to analyze the methods and tools used by the students, allowing for better preparation for use in future courses and projects. Siemens Teamcenter PDM software was purchased in advance and integrated into the existing CAD environment. Scientific staffs at all locations were then trained in the application of the software. In addition, a communication environment based on Adobe Connect (available from the German Research Network (DFN)) was established, allowing for multi-site development.

## 2 DISTRIBUTED DEVELOPMENT

Cross-Enterprise Engineering comprises distributed, coordinated collaboration during product development [2]. Development tasks are typically carried out via email, videoconferencing, and other collaboration software. For successful implementation of distributed development, Enterprise Resource Planning (ERP) is typically used to allocate available resources in an enterprise (capital, equipment or personnel) as efficiently as possible and optimize business processes. Product data management (PDM) and product lifecycle management (PLM) tools are used together with CAD and CAE tools during the entire development process, from product definition through validation and manufacture.

Development may occur within one company at distributed locations or among various global companies, depending on the organization structure of the project and how development tasks are distributed. In a unit-specific model, teams are organized by product modules, with module A being designed at location A, Module B being designed at location B, with teams at all locations working together to be certain that all geometric and functional connections are considered. These interfaces are typically double-checked in the virtual realm, using the aforementioned computer modelling and simulation tools. With a subject-specific model, teams are made up engineers within the same discipline or specialization work together from different locations. In this way, a team could be working on the same module or sub-system of a product but spread across several locations. External companies are given development tasks when a company utilizes an outsourcing model.

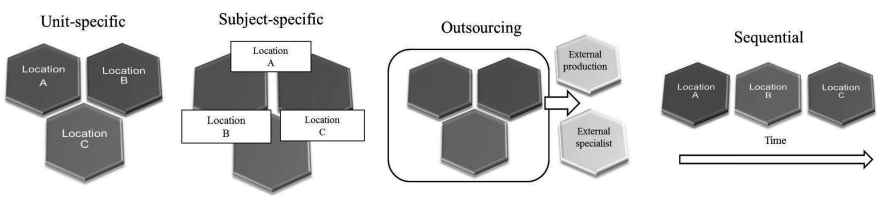


*Figure 1. Development Organizational Model [3])*

There are many challenges associated with distributed development. Regardless of organizational structure, communication is essential for successful product development [4]. Team members need to be working on the latest models and with the most up-to-date information relevant to their components or sub-systems. This information exchange is easier when teams are co-located rather than distributed around the world. Issues can be easily and quickly resolved when one knows exactly who to speak with and the communication can be done face-to-face. When colleagues are working from multiple locations that don't allow for personal meetings, there exist many challenges to communication, such as organizing meetings across different time zones, issues with language, and other cultural differences [2].

Challenges also exist with the integration of various CAD and CAE tools. This is especially true for development across multiple companies, with each possibly using a different CAD or CAE vendor. IT tools applied can vary as well, making the exchange of data amongst various locations difficult. While many tools exist to assist with communication and collaboration among distributed teams, learning these tools and acquiring skills is not always part of an engineering curriculum.

## 3 IMPLEMENTATION

The project "Computer-aided Product Development" was implemented over several stages:

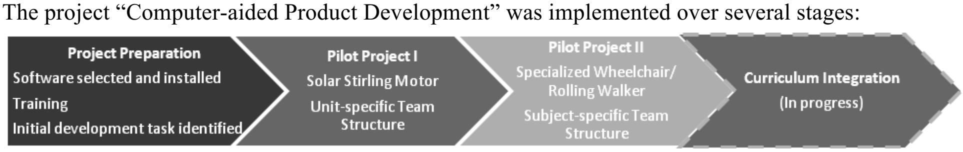


*Figure 2. Project Sequence*

### 3.1 Project Preparation

Starting in winter semester 2012, the first semester was used by the scientific/instructional staff to work out logistics for the project. Of highest importance was preparing the labs and infrastructure so that the development environment mirrored as closely as possible that found in industry. Engineers spend a significant part of the development process on design, with CAD and CAE software being essential tools. Three-dimensional modelling, product assembly models, and the ability to produce manufacturing drawings with Bill of Materials are relevant technical skills for students to acquire.

Creo 2.0 by Parametric Technology Corporation (PTC) was selected for solid modelling and assembly creation. However, additional modelling environments may also be used in the future to give students exposure to integration of several packages and exchange formats. Ansys (CAE software) was selected for finite element modelling, but further CAE tools are being considered based on availability within each of the participating institutes. To enable extensive documentation required of students to support design decisions and development planning, MS Office products were selected as every school had access.

Videoconferences between instructional staff as well as students were carried out using Adobe Connect through the German National Research and Education Network (DFN), which enabled document sharing and audio and video communication. The PDM software Teamcenter was hosted at the TU- Braunschweig and was accessed by teams in Hannover and Clausthal as well as Braunschweig. The software was chosen based on its popularity in Germany and its relative easiness to configure and use [5].

Also during this first semester, a development task for the first pilot project was agreed upon and defined by the three participating locations. Experience shows that students are more motivated when they perceive they are making a difference or have an impact with their work, and the development task was chosen for both semesters keeping this in mind. Simultaneously, a common engineering design methodology to implement was selected.

### 3.2 Pilot Project I

A development task was defined in cooperation between the three institutions at the beginning of the semester, with the goal being a working prototype at the end of the semester. To kick-off the initial pilot project, a meeting was held at the Hannover location, giving the students an opportunity to meet once at the beginning to discuss the development task face-to-face. During this meeting, the students were given an overview of the task at hand, instruction on using the collaboration software and forum available for communications during the semester and decided jointly on the rules and timing regularity of such communications. In addition, they were instructed to document each of these communications so that supervisors at each location were able to stay informed as well. Given that a prototype was to be built, the students also used this initial meeting to discuss project planning and timing so that enough time was allocated for part orders and manufacturing and build issues. Design reviews were scheduled also during this initial meeting.

The pilot project involved the development of a solar Stirling engine. It was decided to organize the teams using a unit-specific group structure, such that each location was responsible for a sub-assembly of components of the Stirling Motor. This distribution of tasks can be seen visually in Figure 4.

The mirror unit and its components were designed and processed in Hannover, the development of the Stirling engine and control electronics was carried out in Clausthal, and Braunschweig had the tasks of system integration and transport solutions. In terms of distributed development, the main focus in this first project was on the clear definition and clear documentation of the interfaces of the system between the individual sites.

Bachelor and Master Mechanical Engineering students were involved in this pilot project, and the students followed the German guideline for engineering design (VDI 2221) within product development, starting with identifying and clarifying their respective tasks and collecting requirements that resulted in a specification document. A functional decomposition was considered for the entire product by the group as a whole and then decomposed further by each location into sub-functions. The student worked several weeks on generating concepts for each sub-system and presented these ideas in monthly design reviews, also conducted simultaneously over the three locations via a web conference. Students refined their designs using CAD and other computational software and shared files, initially using Dropbox and eventually through Teamcenter PDM.

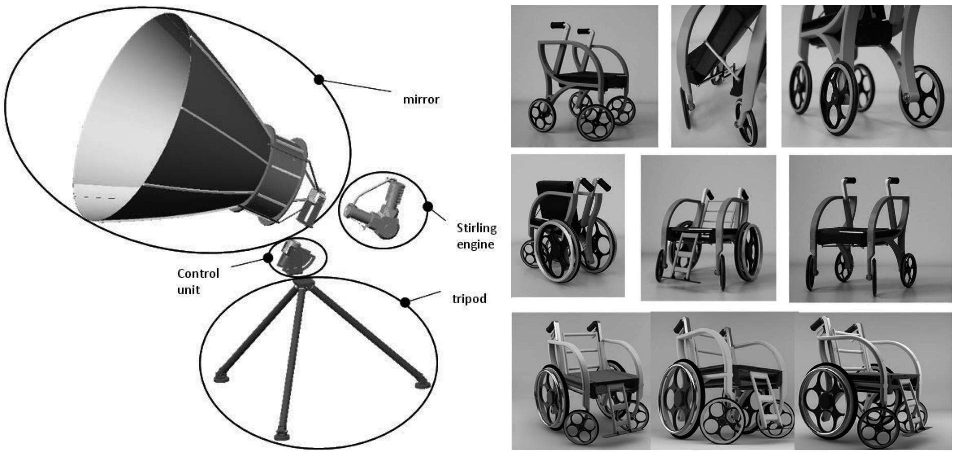


*Figure 3. Pilot Project I Solar Stirling Motor and pilot project II Specialized Wheelchair*

### 3.3 Pilot Project II

The second pilot project utilized the same software as the initial pilot project. Documents were uploaded only to Teamcenter and followed a work flow process during pilot project II, being accepted as official documents only after two out of three supervisors had approved of the documents. Rather than having the teams broken into component groups by location, the teams were instead mixed, with students from two schools working on the same system. The development task for the second project was to design a specialized wheelchair or rolling walker, with each team designing for a different use case. The development task was presented as an open-ended design task, allowing students to creatively identify specific use cases during the kick-off meeting held in Clausthal for the second pilot project. Weekly meetings and design reviews were again used to ensure timely project completion.

## 4 OUTCOME (ANALYSIS)

To better analyze the outcomes of these initial pilot programs and to provide focus for the integration of material into future courses, a total of seven competencies were identified: the ability to work in a team, to use the prescribed design methodology, project management as well as personal time management, CAD skills, communication and the use of collaboration software and tools. These competencies were deemed by the respective Institutes as the outcome of good education and important for future engineers. Each student was individually evaluated by the instructional staff for these skills on a scale from 6 (student is lacking skills and needs training) to 1 (shown competency with skills). The result is shown in Figure 5.

There is a striking variation in results across all competencies that can be partly attributed to the distinct difference in the education levels of the participants. The difference can be explained by individual strengths and weaknesses as well as by the academic progress of the students, since Bachelor and Master students participated together. The outcomes from the initial projects show both strengths and weaknesses in our current respective curriculums. A strength of all students involved is the ability to solve technical problems, but when working in distributed groups, team building and communication made this task more difficult. These difficulties raised awareness in the students that these skills would be of great advantage when leaving University. These two pilot projects also revealed the enormous amount of time necessary to work in distributed development teams. Some of this additional time could be attributed to organizing the projects in such a way that the students were able to finish a prototype of the design by the end of the semester. This required additional time of the supervisors at each location as well, which could be partly due to the complexity of the collaboration tools being used. Before the start of the pilot projects, none of the students had any experience using Teamcenter.

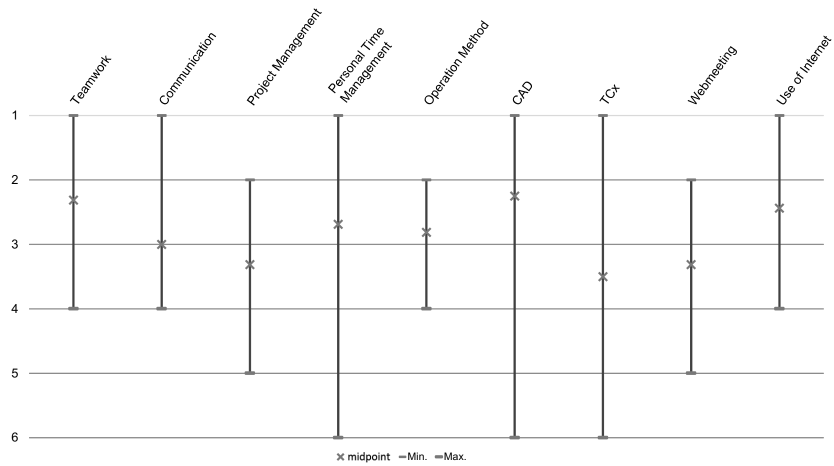


*Figure 4. Student Skill Analysis*

The evaluation shows that while most of our students are comfortable with CAD, a course that has long been a part of the curriculum, many students struggled with the use of Teamcenter (TCX). Since using CAD software caused problems only in individual cases, it may be assumed that the use of computer -aided development tools generally does not constitute a challenge for students and TCX, due to the unfamiliarity with the students and the complexity, is an exception here. Communication between the sites was a significant challenge at the start of the initial pilot project. The students were not only inexperienced with the video conference and collaboration software, but they were also relatively inexperienced in working in teams, as teamwork is not a typical component of previous classes. However, this communication improved throughout the duration of the project. Students became out of necessity group speakers and meetings were organized in advance and carried out with a specific goal in mind. It has been shown that students work together albeit it reluctantly with strangers. Students hold a belief that the project will take longer to finish with teamwork rather than finishing it alone. Another concern is that grading could be adversely affected. These fears are especially prevalent when there is great disparity of knowledge among the stakeholders. At this point, an early and significant intervention by the supervising staff is essential in order both to alleviate these concerns and also to compensate for deficits as early as possible to prevent the risk of frustration. Cultural diversity within the groups created an additional challenge with communication. Non-native German speakers may be more hesitant to join in or may lag behind in the discussion during video conferences.

Also varied was the ability of student project planning and to manage their time and to stay on task to finish a prototype build by the end of the semester. About two -thirds of the students demonstrated good to very good ability to manage time, whereas the remaining students were not able to plan their own work or to adhere to self-set goals. In the future, this can be remedies with closer supervision by the instructional staff with relatively little effort during the early stages of projects. Although the theoretical foundations for these competencies are in place in the curriculum, the students are learning to apply this theory to practice.

## 5 INTEGRATION INTO CURRICULUM

Overall, it became clear following these two pilot projects that additional skills need to be taught as part of the curriculum to allow for students to work in the future in CEE distributed teams.

It was decided to integrate what was learned from the first semester earlier than planned into an advanced lecture in CAD at TU-Braunschweig. As part of this integration, 40 students worked in small groups on a development task using the PDM software Teamcenter. The students were given an introduction to the software and were given the task to modify a Quadcopter for reduced weight and improved safety technical aspects, an example result is shown in Figure 6.

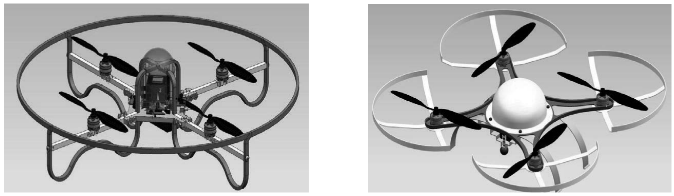

*Figure 5. Lecture Integration in CAD Labour*

To close the knowledge gaps identified during the course of these projects, two lecture modules were created jointly, compiling the basics of CEE as well as technical aspects of the development environment. These lecture modules will be integrated into the CAD course in Braunschweig and CAE lectures in Clausthal and Hannover. Module contents include an explanation of distributed development in conjunction with the motivation and need for its use and demonstrate technologies needed to handle the design projects. These modules are, however, not enough to address the identified shortcomings in the area of soft skills. These skills are best acquired through practical experience on behalf of the students, which can be achieved only with additional time and organization that is not available with the existing lecture structure. One possible solution would be to further develop the group project currently integrated into the lecture at TU-Braunschweig by allowing students from all three schools to work together to complete a similarly-sized development task within a semester. A more comprehensive solution would be to create a NTH Masters program in product development, which allows for conditions for CEE to be better fulfilled. The geographical proximity of the three universities of NTH offers opportunities for practical application of distributed development**.** Furthermore, a new degree program offers more flexibility to integrate soft skills into the curriculum.

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# HARVESTING COLLECTIVE TREND OBSERVATIONS FROM LARGE SCALE STUDY TRIPS

**Kaare ERIKSEN and Nis OVESEN**
Aalborg University

**ABSTRACT**
To enhance industrial design students' decoding and understanding of the technological possibilities and the diversity of needs and preferences in different cultures it is not unusual to arrange study trips where such students acquire a broader view to strengthen their professional skills and approach, hence linking the design education and the design culture of the surrounding world. To improve the professional learning it is useful, though, to facilitate and organize the trips in a way that involves systematic data collection and reporting. This paper presents a method for facilitating study trips for engineering students in architecture & design and the results from crowd-collecting a large amount of trend observations as well as the derived experience from using the method on a large scale study trip. The method has been developed and formalized in relation to study trips with large numbers of students to the annual Milan Design Week and the Milan fair 'I Saloni' in Italy. The present paper describes and evaluates the method, the theory behind it, the practical execution of the trend registration, the results from the activities and future perspectives.

*Keywords: Study trips, trend analysis, industrial design, trend observation, innovation.*

## 1 INTRODUCTION

Study trips have a long and strong tradition in design programs at Danish universities as an addition to sources of knowledge and inspiration given in literature lectures and project work. Such trips enable in situ observation of spaces, objects and places which you have only heard of or seen on a screen. For generations Scandinavian designers have incorporated inspiration from study trips into their design projects in architecture, product design and fashion. Furniture designers like Hans J.Wegner, Børge Mogensen and Ole Wanscher were inspired by Chinese [1] North American, Spanish as well as Egyptian chairs [2], and the first Danish industrial designer, K.V.Engelhardt, thoroughly studied and got inspired from tools and products on a trip to Japan back in 1923-24 [3] . A study trip to USA in 1950 later inspired the Swedish designer Sigvard Bernadotte to set up an influential industrial design studio collaborating with a range of Scandinavian manufacturers [4]. In 1976 industrial design professor Arne Karlsen [5] argued that the primary aim for industrial design students' study trips should be to experience with their senses and deduct valuable generic design principles by studying fine architecture and public space detailing. He sees this as a reaction to a previous trend from the late 1960's, where study trips focused more on studying behavioral patterns or registering socio-technical phenomena. He warned about the danger of unreflected documentation overload and suggested a systematic and organized data collection by studying the details of a specific building or public space, hence expressing a 20$^{th}$ century approach, where products were seen as architectural detailing and not as consumer goods for a market..

At the Industrial Design program at Aalborg University, we have for some years likewise tried to optimize systematic learning from the design students' study trips [6] by adding workshops, exercises or specific tasks to ensure that the study trips differ from less structured excursions arranged by the students themselves or ordinary holiday trips.

Initially, the structuring of the students' learning in relation to study trips consisted of a concept where a small group of students wrote and edited a Study Trip Guide based on the preliminary studies of the works, businesses, museums or studios that they would visit on the study trip. The study trip guide was prepared *before* the study trip hence, making it a useful bank of information on tour, but the students were not required to collect or handle impulses or knowledge that the they obtained *during* the study trip. Several study trips have also been organized around a workshop with students from a local university in another country such as China or Mexico. The visible results of such trips were the presentation of the projects that the students developed in such a multicultural context.

On later study trips, we have tried out models where the students helped to define the study topics in advance and then formed student teams who collected data on the trip for processing after returning home [6].Travelling can be stressful, though, and the students might not stay at the same hotel or might not have had the opportunity to plan the data collection and align the ambitions or methods for data collection before the trip. These conditions can make it difficult to perform effectively in a joint project group on tour and they can result in more scattered or unstructured data collection and a situation, where a single conscientious student or a pair of students end up writing the report after the trip while the other group members simply skip the task.

## 2 THE STUDY TRIP TASK OBJECTIVES

On the basis of more than ten years of experience, we developed in 2013 a model with a more dynamic, effective and manageable structure and specific goals for the study group assignments. The concept can be summed up in these Study Trip Task Objectives:

The study trip should:

1. adapt to the specific data that could be observed at the specific location;
2. ensure that each student was given a specific task to be solved individually;
3. make it possible to solve the task ON the trip without preparation and by using available remedies;
4. involve an assignment that could be uploaded without a substantial work load;
5. include identical assignments for all students;
6. yield data collection that would give a broad and valid response and a clearer picture than each individual data collection would give;
7. yield results to be directly or indirectly used in later student project works, research or studies.

The concept was tested on a study trip to Rome and Milan with 145 first year students in Industrial Design and Architecture. A series of individual tasks in architectural studies (including sketching exercises and photo records) were given in Rome after which the students were given a number of tasks related to furniture and product design in Milan. To manage such a big group of students we had to develop tasks that were very well defined and could be solved regardless of the variety in the students' individual skills and preconceptions.

## 3 THE TREND OBSERVATION

Among the assignments to be undertaken in Milan was a *trend observation* exercise where each student acted as an independent observer of phenomena that could be defined as a current and visible trend. While trend research is often defined as a cross disciplinary task, where society patterns, movements and relations are analyzed, it is also recognized among professional trend forecasters, that every individual or organization could establish trend spotting themselves by simply collecting, arranging and discussing the infinite amount of signals that we meet in our everyday life [7]. We therefore presented a very open approach to trend observation, where each student was asked to fill out a template for registering '*a phenomena in form, surfaces, details, materials, general compositions etc. which can be said to express a current or new trend'*. In order to ensure that the observed trend is not just a casual observation, each trend should be documented by at least three images picturing the described phenomenon as seen at the Milano furniture fair or elsewhere in the Milan city district.

Moreover the students should:

A. name the trend;
B. describe the trend in general;
C. describe the three pictured samples;
D. describe where each observation was recorded.

In figure 1 you can see two samples of trend observations as registered by students in Milan, 2013.

The objectives in relation to the above mentioned study trip objectives could thus be met like this:

1. Milan is a very lively place during the design fair where all the major manufacturers and retailers of furniture and related products show their latest products while plenty of exhibitions and events involving design schools and experimenting designers show the formal and conceptual directions of public interest. This makes it a unique setting for observing trends in a number of product categories, especially within furniture and interior design products;

2. Each student should fill in 2-3 registration sheets based upon their own individual observations;
3. The student should be able to quickly take the necessary snapshots with their phone and complete the data collection in a supplementary paper;

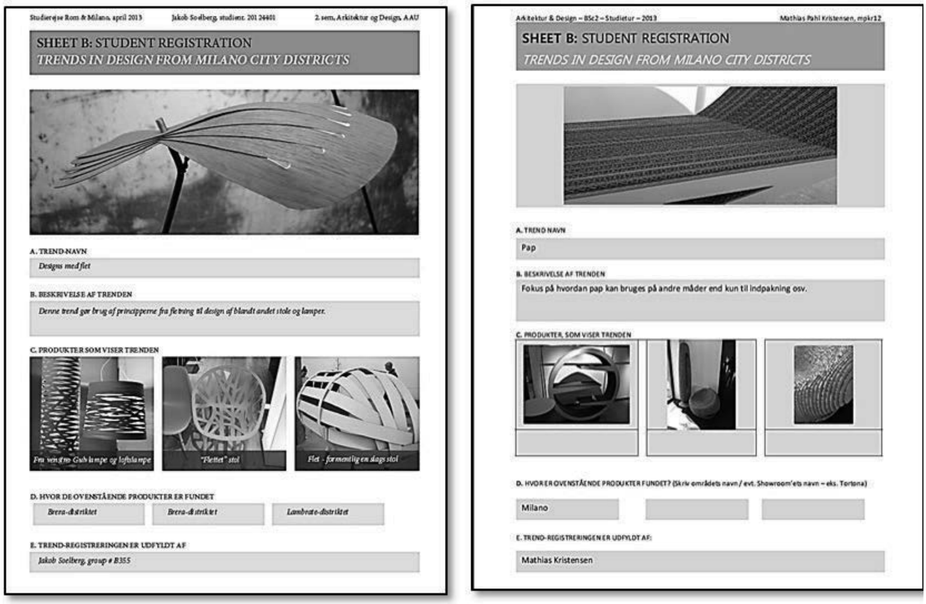


*Figure 1. Samples of students' trend registrations in Milan, 2013: 'Woven structures' and 'Cardboard'*

4. They could then easily upload the data to a digital form, which was available on the www while waiting at the airport or after arriving home;
5. All students were given the same assignment, but only a few answers would be identical because they were based upon individual observations;
6. With a response rate of 86 and an average of 2½ trend reports handed in per student there was generated 315 responses, which gave a broad picture of current trends.
7. The study trip was early in the semester just before the start of a PBL design project, where the project groups were expected to use the observed data directly as a basis for discussion and inspiration for the design of a new product. Indirectly, each of the students also learned to use an active research-like approach, which taught them observe in a more active way than they would do on a conventional holiday trip.

It was the intention that the data obtained during the study trip would constitute a kind of inspirational compendium for the whole group of more than 150 students, but the large amount of data was unfortunately not collected before the design project was finished.

## 4 MILANO TRENDS 2013

There was some variety in the quality and especially in the focus of the collected data. The students were asked to define and name the phenomena that they themselves observed as a pattern to be defined as a kind of trend. By naming each trend in 1-3 words, they could highlight the specific focus that might follow or expand the main categories like surface, detail, materials and general constructions etc. The recorded trends almost exclusively focused on furniture design; obviously as the fair area and the city's attention was directed at this specific product category at the time.

The reported trends were analyzed retrospectively and they could be divided into the following partly overlapping main and sub categories:

**A. MATERIALS & MANUFACTURING METHODS (27%)**

1. Materials (22%): Mainly paper or card board and Plexiglas but also concrete, felt and rubber besides unusual combinations of materials, primarily wood combined with stone or metal;

2. Manufacturing/production methods (5%): ‘Stamped metal’, ‘perforated sheets’, ‘turned wooden parts’, ‘ceramics’, ‘roughly cut out paper’etc.;

**B. SURFACE, COLOR, DÉCOR & TEXTURE (22%)**

3. Surface & color (16%): Mainly shiny or reflecting surfaces (like mirrors used as a main component) but also to some extent the use of neon colors and pastel colors. Transparent and flashy combinations of contrasting colors plus the use of green, yellow and cold blue;
4. Textures and tactility (2%): Soft furniture that looks hard or hard furniture with soft edges. Surfaces with appealing texture.
5. Decorations (4%): Prints and graphic patterns used in surprising new contexts, but also the use of wooden components as a decorative element;

**C. FORM, STRUCTURES & ELEMENTS (17%)**

6. Form geometries (9%): Untraditional use of circular forms, spirals, prismatic (diamant) and organic forms plus basic geometric forms in general. But also beam or pin structures, twisted forms, odd angles and ‘the obsession of thin’;
7. Contrasting elements in general (2%);
8. Origami (3%): The use of motifs or geometry from the traditional Japanese folding technique in furniture and lamps in paper or other materials like metal sheets;
9. Grids/network(4%): Braided or otherwise semi-transparent constructions or sheets in classic materials or new ones or open woven constructions in diverse materials;

**D. GREEN/ENVIRONMENT (9%)**

10. Recycling/reuse/green (9%): Mostly the use of (reused?) card board or reuse of more or less ‘rough’ wooden components. And the use of components with another functionality like whisks for lamps etc.;

**E. THEMATIC FORM KONCEPTS, MOTIVES & DETAILS (18%)**

11. Koncept theme (8%): Mostly aesthetic appearances that relate to topics like ‘industrial’, ‘futurism’, ‘minimalism’, ‘an odd angled world’, ‘humor’, ‘cartoons’, ‘copy ‘n paste’ etc.;
12. Specific motives (3%): Water bubbles or flower-like forms as decorative elements or full corpus constructions, spaghetti-like furniture or lamps, references to animals or animal parts in hangers etc;
13. Composition of elements (4%): The use of ‘small legs’, raw elements in stone or wood, double layer tables, upholstered buttons’, ‘leaned back furniture compositions’, and wooden stick legs;
14. Unusual parts (3%): The use of colored strings and plumbing tubes as constructive and aesthetic elements;

**F. PRODUCT CATEGORIES AND USE (6%)**

15. Principles of use (3%): Products with modularity, multi functionality or untraditional compositions of furniture or room dividers plus the use of free standing toilet interior;
16. Product categories (3%): The revival of the chandelier in crystal or unorthodox materials. The wide spread use of small round tables and classic/old design items in new contexts;

The main categories A-F and the sub categories 1-16 were not named by the students themselves but they were defined by the researchers after analyzing the students’ material. The categories are not following consequent rules for inclusion but most of the categories are probably not surprising to those who follow the current trends in furniture design. If the students’ observations are correct, you could say that the general *remarkable* or upcoming trends in Milan, 2013 were:

*The wide spread use of paper, card board, concrete, copper, mirror and plexiglas in rough or very shiny and often contrasting compositions and surprising but also basic geometries, foldings and perforations/grids added with ‘funny’ or appealing details in textures/tactility often in relation to picturesque themes or more or less ironic references to well-known trends of the 20$^{th}$ century.*

## 5 PERSPECTIVES ON STUDENTS’ TREND OBSERVATIONS

The results from this study raised a number of reflections on what led up to these findings. The students were asked to report on the basis of their immediate observations, meaning that they had not been prepared or had otherwise examined whether the observed trends actually pictured the reality as such. This immediacy has a certain power, but the information was primarily gathered at exhibitions that are set up to create an instant attention. In such a visually very appealing environment the exhibitors need to create attention by often using strong colours and special effects, and the most spectacular or contrasting products may be put in the frontline, while more sellable products might be arranged more discreet in the background.

The frequent observation that paper and cardboard products are merging in interior decoration and furniture design may be due to the fact that many students' experimenting stands or smaller start-up companies without significant impact focus on especially such materials that do not require big investments or advanced production facilities. Many such observations *can* therefore be right, though, and in fact corresponding trends *are* often mentioned in many interior design magazines and web shops these years.

Other explanations for several of the observed trends may be completely different. A common hermeneutical principle is that you observe and interpret from a pre-understanding, and in this case the point of departure is the pre-understanding of Scandinavian freshmen students who have not finished their first year of studying design and engineering. It would take too far to dissect these students' backgrounds and mental filters in their observations, but you could for instance take the following views:

1. The students primarily observe what they are familiar with and what they like.
2. The students primarily observe what they are NOT familiar with and find new and unusual.

**LOOKING FOR THE FAMILIAR AND ATTRACTIVE (1)**

The students could tend to notify stands and places that they simply found attractive as they haven't got the deep specialist knowledge to make them see the underlying innovations such as less visible construction principles or manufacturing methods. The invention of a revolutionary new tilting bracket might for example have been overlooked by the students even though the professionals would reckon it as a strong invention to promote a whole new generation of comfi-chairs. The discovery of trends would have required that the students more actively analyzed the stands and asked what the individual exhibitors considered most innovative.

A considerable part of the exhibition area displayed 'classic furniture' addressed to an elder generation or the contract market for hotels etc. Such objects do not appear in the students' observations, even though trends and innovations should be visible in this area as well. This is probably due largely to the fact that students simply haven't sought out these stands. At the same time many students have several observations from more appealing and experimental stands or from showrooms in Milan's avant-garde neighborhoods, Tortona and Breda.

Similarly, the consideration that many new products are based on origami folding technique may simply be due to the fact that the students had an origami-course just a few months before visiting the furniture fair.

**LOOKING FOR THE UNFAMILIAR AND NEW (2)**

On the other hand there could be a tendency that the students primarily observe the products that they do not know from their own culture. The Scandinavian design culture is characterized by preferences for ease, simplicity (IKEA is Scandinavian) and natural materials as well as a rare use of very shiny surfaces. The observation of the widespread use of natural materials and simple geometries speak against this and make no reason to believe that there actually IS an international trend in interior design, which refers to Scandinavian design paradigms. Some students' perception that glossy surfaces is a new international trend, on the other hand, might come from the fact that they are not used to the glossy surface finish that is prevalent and desired in southern Europe and in most parts of the world in general.

It would be very interesting to filter out the layers in the students' observations that are too biased by the students' own cultural background. To do so, it would be useful to set up a parallel observation team of students from for instance an Italian university or a university outside Europe and compare the different students' findings.

## 6 THE STUDENTS' LEARNING AND FURTHER PERSPECTIVES

It is difficult to measure the students' learnings from this study, mainly because the observed trends were not collected into an inspirational catalogue as previously planned. The students could therefore not use such an inspirational palette as the source for the design project that was scheduled after the return to the home university. Nevertheless the exercise provided the students with an insight in interior design, and the most important learning might be that the students through this exercise were forced to actively observe and record design relevant phenomena in a real physical context which is not fully coherent with the digital media, where students often find inspiration or information on the

Chapter 5

# DESIGN EDUCATION AND DESIGN CULTURES

# WHY DESIGNERS AND PHILOSOPHERS SHOULD MEET IN SCHOOL

**Liesbeth STAM[1] and Wouter EGGINK[2]**
[1]Industrial Design Engineering, University of Twente
[2]Faculty of Engineering Technology, University of Twente

**ABSTRACT**
Many scholars who study user-technology relations have shown from different perspectives that such relations are mutually constructive: users shape technology, and technology shapes users. This awareness raises questions about the part a designer plays in the workings of society. Are designers responsible for the social role of their products? Can designers promote the well-being of users and society at large? These questions are still largely absent in design education. In this paper we argue the importance and benefit of integrating concepts from Philosophy of Technology and the related field of Science and Technology Studies (STS) in design education. We will discuss a threefold benefit of a combined approach that draws on both traditional design education (generally focused on individual users and objects) and theoretical approaches to technology (generally focused on how technology marks and transforms the way we live our lives). In the first place such an integrated approach enables a deeper insight in the social significance of design. Secondly, it allows for a better understanding of design theory and practice itself. Thirdly, it provides a basis for the development of new design perspectives that promote human well-being. To illustrate we will introduce the notion of '*open script design*' as a new design perspective that was developed in a Capita Selecta design course based on insights from philosophy of technology and STS.

*Keywords: Design for Well-being, Philosophy of Technology, Science and Technology Studies, Design Theory, Open Script Design*

## 1 INTRODUCTION

Design is everywhere. Our daily lives are so deeply intertwined with design that it is hard to imagine any experiences that are free from its touch. At the same time it is difficult to see and understand the myriad ways in which design influences our lives – how it shapes daily practices, how it changes the way we interact with others and how it sets new social forms.

Dorrestijn and Verbeek [1] assert that implicitly or explicitly designers always affect the well-being and lives of users and society at large: in a direct sense because products fulfil existing needs, but also in a more indirect sense because products affect the behaviour, attitudes and needs of users. Facebook may fulfil a need to maintain contact with friends, but it may also consciously or unconsciously renegotiate the meaning of friendship and change the rules and practice of inter-personal relationships. Similarly, mp3 players have renegotiated the meaning of music by establishing new ways of listening, obtaining and owning music. Likewise, digital cameras renegotiated the meaning of memories, by changing how and what events we capture.

The awareness that technology guides and changes the way we live our lives raises critical questions; not only for governance and ethics, but – as will be the theme of this paper – also about the part that designers play in the workings of society. Are designers responsible for the social role of their products? What is the agency of a designer in shaping user behaviour, and in a larger context in shaping society? Can designers employ user-influencing effects to address the ills of contemporary society and promote human well-being? Although design discourse is becoming increasingly aware of these questions and their importance, in practice designers are still searching for footing when dealing with these issues. Dorrestijn [2] asserts that it is an important task and challenge for designers to understand and cope with the influences of technology on our lives and well-being. In pursuit of this challenge we aim to advance 'design for well-being', where we consider well-being in its broadest sense, as 'what is ultimately good *for* a person'. In this paper we argue the importance and benefit of integrating insights from theoretical approaches to technology in design education; especially from philosophy of technology and the related and interdisciplinary field of science and technology studies (STS).

What brings together design and theoretical, philosophical reflection on technology is the shared interest in the mutual adaption of humans and technology [1]. However, designers and philosophers take on radically different perspectives [3, p.212]. While philosophers are principally concerned with *understanding*, and *reflecting on* human-technology relations, designers are more pragmatic and interested in *shaping* human-technology relations. We believe that to advance our understanding and practice of how humans and technology are best adapted to each other, both perspectives are essential. Therefore, in this paper we will discuss a threefold benefit of an integrated approach to design that draws on both traditional design education and theoretical approaches to technology. First we will discuss how an integrated approach enables a deeper insight in the social significance of design. Secondly we will show how socio-historical reflection allows a better understanding of (the development of) design theory and practice, and in the third section we will illustrate how an integrated approach can form a basis for the development of new design perspectives that promote human well-being.

## 2 SOCIAL SIGNIFICANCE OF DESIGN

The examples in the introduction emphasize the importance of investigating the social role of design and the agency of designers to promote well-being. To be able to analyse and consciously cope with the social aspects of product design, it is important for designers to develop an understanding of how technologies guide and change our lives.

Philosophers of technology have offered insightful analysis of how technology helps to shape human existence. During the past couple of decades, philosophy of technology increasingly started to interact with fields like STS, culture studies and media and communication studies [4]. This led to a family of approaches to technology that is more empirically informed than classical approaches. Instead of studying technology in its entirety, contemporary approaches illuminate aspects of what can be called 'technical mediation' and focus on concrete technological artefacts and the part these play in shaping human actions and experiences. Examples of philosophers in this tradition are Don Ihde, Albert Borgmann, and Peter-Paul Verbeek [e.g. 5, 6, 7]. Their work is influenced by the field of STS, and according to Franssen et al. [8] by two ideas in particular: the idea that technological artefacts contain scripts, which can be understood as instruction manuals that are implicitly or explicitly inscribed in objects and influence human behaviour; and the idea that material objects must be considered as sources of morality and politics [e.g. 9, 10].

The 'empirical turn' has rendered contemporary approaches in philosophy of technology more suitable for application in design. Moreover, associated with the turn towards user-centred design we believe that present design theory and practice is quite receptive for the inclusion of concepts from philosophy of technology and STS. Since the 1980s usability is becoming an ever more important issue in product development. As a consequence of the focus shift from technology to the user, designers have moved away from technology-driven development and increasingly approach product development from the perspective of human-technology relations. Today's designers are well trained in shaping user-product relations, for example by applying techniques associated with Scenario Based Design [11]. In present-day design, instead of functionality, usability has become the central criterion of what is 'good design'. However, awareness is rising that 'good design' entails more, and that it can be captured by neither functionality nor usability alone.

This awareness has recently yielded several initiatives that aim to understand 'good design' in terms of well-being. Several design approaches have been developed that make well-being an explicit design concern. Value Sensitive Design was developed in the field of computer ethics and seeks to provide theory and method to account for human values throughout the design process [cf. 12]. Life-Based Design takes a holistic approach to human-technology interaction, looking at people's whole life and the role of technology in them [e.g. 13]. Furthermore capability approaches to design assume that well-being is dependent on a set of basic capabilities (e.g., capability to be adequately nourished) and that technology can extend human capabilities [e.g. 14]. However, most of these methodologies suffer the critique of being vague and still under-developed. Moreover, many of these initiatives are developed outside of traditional design disciplines and are as yet scarcely known to designers.

An exception is the family of design methodologies that can be referred to as *emotional design*. The past few years emotional design approaches have received growing attention in both design research and education. These approaches are concerned with how the physical design of products can induce positive feelings and emotions, or contribute to the experience of immersion, flow or mindfulness. Jordan [15] for example developed a design methodology based on the idea that designers should not just design for functionality and usability, but also for pleasure. And Norman [16] suggested that designers should take into account the emotional response of users to products and ensure that products evoke positive feelings.

What is promising is that these developments show that designers move away from the traditional, but obsolete premise that products are 'neutral carriers of will' that simply help to achieve a certain goal more effectively or efficiently. However, although the subject of design for well-being is gathering steam there are some important critiques that need consideration. An important critique to both usability and emotional approaches to design is that they predominantly focus on how products affect (the mental state of) users while products are being used and perceived. More lasting or in-direct consequences for well-being are generally not considered. For example, the design of new social media is predominantly focussed on usability concerns: making human communication easier, less risky and more immediately satisfying [17]. Accordingly there is much attention for improving accessibility and engagement of social media. More lasting or in-directs effects on the user's life as a whole or on a societal level are generally not considered, like the impact of new social media on the development of our character. Vallor notes how current studies predominantly focus on immediate psychological impact of social media, while they are indifferent to the impact of social media on the development of social and communicative virtues. She shows how the immediate nature of social media impedes the development of patience, honesty and empathy which are essential social virtues in developing and sustaining human connections. She comments that '*Today's technologies provide us with an ever-widening horizon of escape routes from any interaction that has lost its momentary appeal'*[17, p.196]. Vallor warns for the adverse effect on our well-being, and calls out to designers to acknowledge the importance of these virtues and to invest in building on them.

The fact that more in-direct and long-term social consequences of technology on our lives and well-being are often not considered can be associated with the inclination of contemporary design theory and practice to focus on individual objects and users [18]. There is little attention for the wider social context and significance of design. This is recognized by Poynor [19, p.178] who comments that: '*when the possibility is raised that design might have broader purposes, potential and meanings, designers who have grown up in a commercial climate often find this hard to believe*'. To underline this statement he quotes graphic designer and educator McCoy who asserts that: '*we have trained a profession that feels political or social concerns are either extraneous to our work or inappropriate.*'

However, as the unavoidable nature of technical mediation implies, technologies always have a social role and will always affect the way we live our lives: the design of new social media will undoubtedly have a major impact on the communicative habits of future generations. Certainly, this is not necessarily a good or bad thing: throughout human existence we have always adapted and renegotiated ourselves in the light of new technologies. Yet, if we want to make well-being an explicit design consideration we must contemplate design choices in a wider social and political context. Moreover, we argue that our growing insight in the mediating power of technology and the awareness that we can actively employ user-influencing effects of technology in the physical design of products give designers the responsibility to consider the social roles of their designs. We acknowledge that technology will always have unintended consequences, and that the social role of design is determined by many actors, among whom users. This means that designers can never be solely responsible for the social role of their designs; they are however co-responsible.

Enriching design education with insights from philosophy of technology and STS will help designers to take this responsibility. A thorough understanding of technical mediation and developing sociological imagination will help designers to envision the social roles of their design. Interesting trajectories that can guide designers in understanding and deploying user influencing effects of technology are for example philosophy of technical mediation [cf. 7] and script-analysis [cf. 9]. Furthermore, the work of STS scholars is interesting for designers as it can contribute to their awareness of the mutual construction of technology and society. STS scholars have developed many theoretical frameworks that aim to understand the dynamic interweaving of activities between technology developers and users in the innovation process. Among such trajectories are the Social

Construction of Technology [cf. 20], Actor-Network Theory [cf. 21] and Domestication Theory [cf. 22]. Finally, as most these trajectories fall within its scope, we would like to emphasize the general importance of ethics of technology (especially in terms of well-being). We realize that asking designers to engage with public issues and social contexts unavoidably means that designers must take ethical and political stances on things. Therefore we believe it is important for designers to engage in the question of 'the good life' and develop basic skill in ethics and ethical reasoning.

## 3 SOCIAL SIGNIFICANCE OF DESIGN

Engaging in a dialogue with theoretical approaches to technology is furthermore valuable because it will help designers to develop socio-historical awareness which allows a better understanding of (the development of) design theory and practice itself. In this section we will try to show how the typical way in which we design cannot be understood in isolation of the characteristics of society, but that design theory and practice develop in a dialectic process with society.

Present-day design is characterized by a focus on individual objects and user. The fact that social and political concerns are generally not considered in the development of consumer products can be understood in view of our Zeitgeist. In our liberal democracy individual autonomy and protecting the rights of individuals is at the top of our agenda. Bauman [23] explains how our present-day situation emerged from aversion to the totalitarian, utopian tendencies of modern industrialized societies, which were accused of rigid discipline and social repression. The dystopian image of all-embracing, enforced homogeneity was a major drive to set out and liberate the individual from any constraints that could possibly limit his freedom to choose and act. However, Bauman also shows that the unparalleled freedom that today's society offers its members comes at considerable costs. Our postmodern society is marked by perpetual change and unprecedented uncertainty.

Design theory and practice developed much in correlation. Many modernist designers were driven by a strong utopian program and were explicitly concerned with improving people's way of living by means of design. Captured by his motto '*savoir d'habiter, savoir vivre*' Le Corbusier believed that the design of the dwelling would assist the people in the process of 'knowing how to live well' and in becoming capable members of utopia. This exemplifies the modernist belief that the built environment could (and should) mould human behaviour [24]. Also, in accordance with the belief in a grand narrative and universal truths, modernist designers followed the idea that for each product an ideal type exists. They designed for the *homo universalis* and denied the diversity of users which led to collective and anonymous designs.

Postmodernists strongly disapproved of utopian beliefs and strivings and rebelled against a totalizing world picture. They encouraged people to pursue their own ways of living. Accordingly, improving society would no longer be an explicit design consideration. The utterly repressing idea of the ideal type was rejected and diversity became the emancipatory theme in the postmodern design paradigm instead. According to Dorrestijn and Verbeek our contemporary design paradigm can be referred to as the paradigm of '*unhindered plurality*' that aims to support an '*unrestricted diversity of singular lifestyles*'[1, p.7]. Although the advent of postmodernism meant the end of paternalism and social repression, the contemporary design paradigm of unhindered plurality introduces its own set of problems fostering consumerism and hyperchoice [25].

This historical reflection shows how artefacts developed in a certain type of society reflect and reinforce the values that are inherent to that society. Our contemporary design paradigm fosters and preserves the structures of consumer society by emphasizing diversity, leading to increasing product segmentation, but also by promoting instant gratification. Facebook, mp3-players and digital cameras for example all embody immediacy and novelty: instant messages, instant photos and on-demand music heighten people's sense of urgency and need for instant gratification which encourages the consumerist attitude. Furthermore this historical reflection shows a development of increasing and decreasing social engagement in design. According to Dorrestijn and Verbeek [1, p.8] the underlying ethical and political theme is the struggle between human freedom and the power of technology to govern people's way of living. It seems that neither an exclusive focus on individual freedom, nor an exclusive focus on the collective and social cause is desirable in design practice. Dorrestijn and Verbeek pose the question '*whether, in the attempt to evade the dangers of domination by and via technology, the influences of technology have not come to be too much underestimated or neglected.*' And set the challenge '*to fully acknowledge the mediating of behaviour and ways of living by technology, and to employ this for enhancing well-being in a moderate and wise way [...].*'

## 4 OPEN SCRIPT DESIGN

The previous sections have both discussed how philosophical, theoretical reflection of technology has potential to enrich design education and advance design for well-being. Another advantage is that acknowledging technical mediation and sociological imagination will lead to new design approaches. To illustrate this argument we will introduce the concept of '*open script design*' that was developed in a Capita Selecta course using concepts from philosophy of technology and STS [26].

Against the background of the unsustainability of contemporary life, the central theme of the Capita Selecta project was the relationship between consumer behaviour and well-being. One of the project's objectives was to understand how design can make a difference in consumerism and establishing well-being as the purpose of consumption.

In today's society consumption has become a goal in itself: we are caught in the infinite cycle of desire -desire, acquisition, reformulation of desire, *ad infinitum*. This cycle pressures us to continuously move on to 'the next', resulting in the ceaseless succession of goods. While, following Tiberius' value fulfilment theory [27], not the succession of goods, but coming to care about our products is what contributes to our well-being. To regain focus on the things themselves, it is necessary to re-conceptualize our notion of consumption. Influenced by domestication theory, we argue that understanding consumption in the act of appropriation (making something your own), rather than in the act of buying, will help to establish well-being as the purpose of consumption. 'Making something your own' may include the act of buying, but comprises a broader set of actions such as giving the object a place in your home and in your routines.

So how can we support this re-conceptualization of consumption by means of design? In answer, elaborating Akrich's concept of script, we proposed the notion of *open script design*. Designers, through anticipating future use, implicitly or explicitly build in use-prescriptions in the materiality of products. However, instead of inescapably following the designer's script, users interpret the script in their own way. Employing open scripts means that designers deliberately increase the *interpretative flexibility* [20] and assign an active role to the consumer to appropriate the product. And, to discourage product segmentation, open script design challenges designers to address a wide as possible target group and use the actual differences between users to differentiate products. To illustrate, clay is the archetype of open script. As a toy, this substance has a wide social application - both boys and girls over a wide range of ages like to play with it. Clay depends on the diversity of users and their input to differentiate the play. Girls can play in a girl-like fashion with clay, and it can support them in their femininity without prescribing what femininity exactly is (e.g., in contrast with Barbie dolls).

Employing open scripts in product design encourages the consumer to see that products are not rigid entities, but that users are active agents in shaping their products by moulding them into their lives and daily routines. We believe that open script design can support an attitude change and convey that consumption reaches further than 'pulling your wallet,' but that it means to fit your products into your life in a way that is meaningful for you. As such, open script design might be a step towards establishing well-being as the purpose of consumption.

Although the concept of open script design is still under-developed we believe it is promising; not only in changing consumer behaviour, but as a new and interesting way to articulate the social importance of design. Open script design can guide designers in employing user-influencing effects to illicit positive social behaviour by means of scripts. At the same time the increased interpretative flexibility emphasizes the co-responsibility of users in shaping the social role of products.

## 5 CONCLUSION

In this paper we have argued that insights from philosophy of technology and STS have great potential to enrich design education and advance design for well-being. To make well-being an explicit design consideration it is important that designers contemplate their design choices in a wider social and political context. This emphasizes the importance to revive the discussion on how we can sensibly include ethics of technology and the subject of well-being in design education. Encouraging designers to engage with deeper philosophical issues about their practice and research will contribute to a more profound understanding of design, especially as a social and political force. Fully acknowledging technical mediation will help designers to learn how to moderately and wisely employ user-influencing effects of technology to enhance human well-being. While sociological imagination will make designers more aware of the power of design and help them to envision how their designs can contribute to a more desirable future.

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# CULTURAL STUDY IN DESIGN: IN SEARCH OF A MEANINGFUL APPROACH

**Annemiek VAN BOEIJEN**
Delft University of Technology, The Netherlands

**ABSTRACT**
Does the Circuit of Culture help design students to do a cultural study that is meaningful for their design project? Indeed, it provides a good view on the phenomenon culture, its complexity and how contemporary cultures can be studied, providing an overview and structure of the processes that influence cultural change. However, there are difficulties that need extra attention; (1) clear definitions of the process elements and their interrelationships; (2) a method or possible procedure to carry out a cultural study; (3) guidelines to determine and demarcate the cultural study in such a way that it contributes to the project assignment; (4) examples of how insights from a cultural study can contribute to the development of a design vision; (5) an extra lens to look at culture to distinguish it from the individual and the universal; (6) discouraging the use of the model as a checklist and (7) discussion about the designers' influence on culture and society.

*Keywords: Circuit of culture, design education, design research methods, cultural study*

## 1 INTRODUCTION TO THE TOPIC OF THIS PAPER

This paper presents a study about how master design students can be taught to do a cultural study in the context of their design project. Reasons for this study are the barriers that design educators encounter when they teach design students to incorporate social and cultural aspects in design. From a more than 12 years experience in design education I learned that design students would rather focus on the solution of usage problems and focus on utilitarian values of their designs than finding possibilities and meanings related to socio-cultural values. The design faculty, that is embedded in a technical university, attracting those students and staff who are interested in solving primary functional problems, is an argument to explain this focus. However, there is also a more generic opinion about designers' focus. For example, Boradkar writes *'In design, our present understanding of objects is only partial; it continues to be predominated more by aesthetics and technological concerns rather than social and cultural ones'* [1]. In less technical oriented design schools this may not be true, but in our school extra effort is needed to make design students aware of the relevance and possibilities to cope and play with social and cultural values, meaning and impact of artefacts. This need connects to a growing interest in the design discipline in the social impact of design. The development of methods, such as Socionas [2] and models to support designers to design social consciously [3,4] are manifestations of this trend. An increasingly globalizing world and an increasing number of people who have access to new products, evoke the question to designers how to deal with cultural values and meaning. Which specific values do their products mediate? For example, a mobile phone with an application that offers the possibility to have multiple contact-lists supports the social value of sharing products. This idea elicited from a Nokia study in India [5]. Researchers found that people were used to share their mobile phones with each other. The challenge in design teaching is how design students can be supported in the development of a lens to look at culture. That would help us to overcome the three identified barriers; (1) a weak understanding of the relevance of a cultural study (why), (2) weak understanding of what is culture, a definition (what) and (3) a lack of a systematic approach to study culture (how). One approach to overcome these barriers is to teach design students to use the Circuit of Culture (CoC), developed by the culture theorists du Gay et al. [6]. We applied this model in the sub-course Design, Culture and Society (DCS), which is part of the course Advanced Concept Design (ACD). This paper presents and discusses the barriers and potential for using this model in the context of a design project.

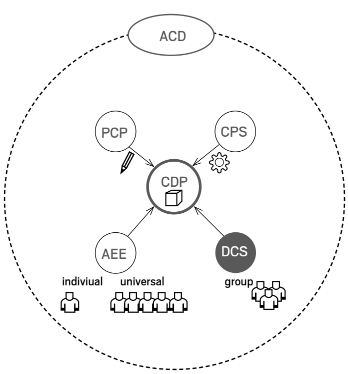
## 2 HOW IT STARTED

### 2.1 Design, Culture and Society (DCS), sub-course in Advanced Concept Design (ACD)

DCS is a sub-course that, together with Applied Ergonomics Exploration (AEE), Cyber-Physical Systems (CPS) and Product Communication and Presentation (PCP), contribute to Advanced Concept Design (ACD), a design course in which students work for one semester on a Concept Design Project (CDP) for real clients, such as Philips and KLM. A design coach supports students for the CPS, accompanied by experts of the sub-courses (see figure 1a). Each sub-course contributes to a specific part and links its learning goals and activities to the CDP. The first quarter is focused on design research, resulting into a design vision for the CDP. For DCS, students are asked to carry out a cultural study, related and relevant to the topic of their CDP. The deliverable is a report, including the research questions, methods & results and opportunities for design. DCS offers 5 lectures and 4 expert meetings in the first quarter, followed by 4 lectures and 2 elective expert meetings in the second quarter. The Circuit of Culture (see figure 1b), explained in *Doing Cultural Studies: The story of the Sony Walkman* [6], has been chosen as a model to understand culture. Students were asked to read the book, attended the accompanied lectures and to attend expert meetings.

### 2.2 Circuit of Culture (CoC), a brief explanation

The Circuit of Culture is a model that can be used as a tool to explore and analyse how cultural meanings, represented by language and artefacts (cultural objects), come about and how they change over time. The development of circuit models already started in the 1970's by Stuart Hall and other members of the British Centre for Contemporary Cultural Studies. In 1986, Richard Johnson published a first version [7]. Cultural theorists, who published a series of books for UK Open University [8,9,10,11,12], further developed this model. The circuit is a metaphor for the interrelated processes that steer a cultural phenomenon. It shows 5 processes that all contribute to the production of culture. The arrows indicate that the processes are influenced by each other, but there is no specific order and hierarchy in the model. The process of 'Representation', is about the development of cultural meaning by language and other means of communication, visually and orally, such as in advertisements. 'Identity', is about how social identities develop, such as the young, dynamic, global consumer expressing personal preferences that are associated with the product. The process of 'Production' is about the creation of the product as a meaningful artefact 'produced' or created by the designer and the company. *'In the process, the company constantly seeks to take account and respond to the ways in which consumers are 'appropriating' the products.'* [6]. The process of 'Consumption' is about consumers that highly influence the meaning (and related cultural value) of products. It is an on-going process that is not influenced by the designer and producer only. Consumers create meanings that can be observed by their daily practices. The fifth process is 'Regulation', which is about change in social regulation due to new ways of categorization and use of products; for example, the Walkman bridged the private and public context of use, leading to noise-level regulation in the public environments. The model has been developed and applied by mainly cultural theorists or sociologists.



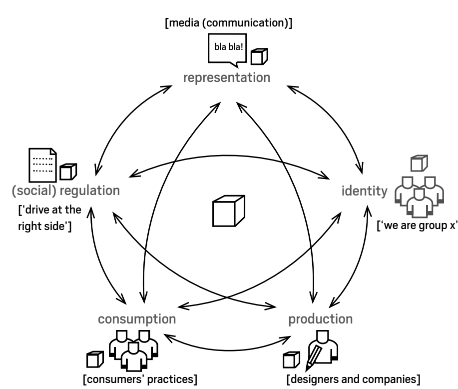




*Figure 1a. Advanced Concept Design course* *1b. The Circuit of Culture (after du Gay et al., 1997)*

## 3 QUESTIONS AND HOW ANSWERS WERE FOUND

For this study the DCS staff wanted to know how the CoC supports designers to do a cultural study and contribute to the development of a design vision. What barriers do students encounter and what opportunities can be identified for the application of this model?

The insights are based on an ACD course evaluation (questionnaires (103 out of 120) and a one hour panel evaluation with 8 students, 4 ACD course coordinators and the faculty education advisor); the evaluation of cultural studies (reports, executed by 24 design teams with 5-6 design students each); online questionnaires (35 out of 128 distributed questionnaires); and an evaluation with the DCS staff (2 hours discussion with 4 design teachers who were coaching and assessing the reports (6 groups each) and a design historian who gave four lectures about the CoC).

## 4 ANSWERS AND DISCUSSSION: WHAT?

The insights derived from the four different sources described in the previous section will be analysed and discussed per source and followed by a general discussion and conclusion.

From the **staff evaluation**: The CoC model was helpful to explain and discuss with students how cultural meanings come about and what the designer's roles and possibilities could be to influence this process. For some projects it was very useful, however, for other projects the application of the model was difficult. For example, for a medical assignment about hip-replacement initially students had difficulties to study 'Representation'. Commercials were not available. It took them some time to understand that other forms of representation, such as information campaigns and websites, could be valuable to study too. Also 'Identity' was difficult in the context of the hip-replacement assignment. Students would rather think about utilitarian values, much more and easier than about cultural ones. Understanding 'Identity' appeared to be much easier for a project about human powered vehicles; A comparison of the identity of two different taxi-tricycle designs in two different cities provided various useful insights about how the identities were influenced by their contexts. In a project for an international airport, students paid a lot of attention to 'Regulation'. The meaning of the arrows in the model seized some students; they wanted to determine the exact relationship between 'Representation' and 'Production'. It seemed that they needed some hierarchy in all these processes and interrelationship to keep an overview. The limitation of the model and the book [6] is that it does not explain how designers could use the model. Both, the experts as well as the students, preferred to have also a method or recipe to use the model that help them to do the cultural study in a systematically way. Another limitation or drawback for designers is that the model is developed to study existing cultural phenomena. Designers tend to go away from the existing, because they want to innovate for the future. Therefore, some students had difficulties to see the relevance of, for example, studying the cultural meaning of existing massage products, while they were asked by the company to design a new 'skin care' product experience for European women. Such broad formulated assignments do not help and motivate students to dive into existing cultural phenomenon. It depends on the formulation and interpretation of the design project assignment to what extend the model is meaningful for them. The staff also discussed that the students tend to search for truths, that the cultural study should give them straight answers that can be translated to concrete and measurable design requirements. This need for a complete and clear set of findings that can be translated into applicable design guidelines was also seen by students who were looking for a 6th element in the CoC. They seemed to see the model as a checklist for a kind of stakeholder analyses. They did not seem to understand the essence of the circuit of criss-crossing interrelated and dynamic processes. A benefit of the CoC was that next to the meaning of artefacts students were also encouraged by understanding the relevance of the meaning of language. For example, in a project for security checkpoints at the airport, the students found that in the vernacular, people used the word bus stop for the security checkpoint and banana for the security device used by the safety guard. The words had a negative connotation, indicating the meaning these artefacts carry in the specific context.

A somewhat worrying finding was that from the 103 **course evaluation questionnaires**: 53.3% answered that they did not study the suggested literature [6]. Nevertheless, the statement '*the DCS area of expertise fits well in the ACD course*' was answered positively (the average score was 8 on a scale of 10). Also the relevance of lectures was evaluated positively (an average of 8) and relevant for the development of a design vision, although the content of the lectures was valued lower (an average of 7). From the list of suggestions and remarks 3 quotes are useful to mention: '*AEE and DCS overlap,* *better distinction required*'; '*the idea to separate AEE, CPS, DCS etcetera was quite confusing and became clear after a couple of weeks'* and *'The Sony Walkman example is out-dated!'*

From the **panel evaluation** it became clear that the students needed time to understand and make the link between DCS and the design project CDP, sometimes even after finishing the course.

From the **cultural studies** (reports): 16 out of the 24 reports explicitly used and/or reflected on the CoC, whereof 8 showed that they understood and used the model as intended, 2 more or less and 6 teams did not use the model in the appropriate way. The CoC served several purposes; to generate culture specific research questions, to discuss and structure findings and to identify the role and influence of the designer. As discussed also with the staff, the model was useful if the assignment could be linked to the material culture of existing products from the present and past, but was more difficult to use if the assignment was broad and open. It took extra time to find an appropriate field of study and then students were less motivated to study the meaning giving process of a product, because they did not see how the outcomes might contribute to their CDP. The reports also showed the complexity of the model. One reported *'In the CoC all terms are connected to each other, which does not only make it hard to understand the term, but also to assign a place to a certain research finding.'* (group 1c, p.51). And in another report: '*The text above tackles the five moments (elements) separately but it does not fully convey the synergistic, interactive, and discursive aspects of the model. All five moments overlap continuously..*' (group 7b, p.39). As reported by the staff, the reports showed that some students were searching for hierarchy in the relationships between the CoC elements, focussing on the meaning of the arrows in the model. Some teams used the model as a checklist, which led to superficial outcomes and others stated that they missed a method to use the model. The model did not help to think of and ask specific questions related to context factors such as, for example, technology, economy, politics and climate. The terms used in the model appeared not to match fully with the understanding of designers. Some student teams used a narrow definition for the terms 'Production' and 'Consumption' referring respectively to manufacturing and purchase behaviour of consumers only, because they are used to use these terms as such. Finally, the students were asked to end their report with 'opportunities for design'. This was added to stimulate them to translate findings to their CDP. Probably, due to a lack of time, but also because not all experts were emphasising the importance and because of the complexity of it, a few results reported these opportunities only. Some reported requirements that were too specific and not appropriate in this stage of the design process.

From the **online-questionnaires** we know that most students see the relevance and utility value for their project of a cultural study. Insights from the study are found inspirational. They also qualify the study as complex. A quote that clearly illustrates this is '*Somewhere in the back of my mind, the theories we learned helped me gain some perspective over the feedback of my respondents. It's really difficult for me because my intended target group was 'globalised, creative middle-class'. How are you supposed to design for culture when the world is filled with Diaspora and sub-cultural complexity? I find it paralyzing to get caught up in the analysis phase and I could use some help framing what's an adequate study (because one can really study cultures forever) and how to draw valuable conclusions from the study.'* The same respondent did not find the CoC useful.

In general, most students welcomed a model that helps them to structure their research, especially for the formulation of questions and set up. A small majority judged the CoC as useful or little useful.

The engineering context of the design school (in a technical university) can explain some difficulties to study culture; the design students are educated to systematically develop and determine a design goal, preferably guided by pragmatic guidelines and measurable criteria. Although the model does not necessarily tunes with these designers' wishes, a merit of the CoC model is that it does help them to understand that designers play a role in cultural processes. The complexity of the processes and limitations of the designer's role to influence the cultural meaning of their designs may discourage them to study culture, taking the cultural impact of their designs for granted. Therefore, more guidance is needed to show them what the understanding of the past and the present means for the future, translating insights into a design goal. Despite the limitations of their influence (especially when commercial media is taking over), they should understand that insights from cultural processes help them to develop a design vision, needed to steer the design direction. If there is not a leading theme there is no direction that steers concept development. Then, the designer will take a risk of being squeezed by his/her stakeholders' opinions and convictions.

1. Next generation human, solar and wind powered vehicles
2. Professional care for elderly in nursery homes with services of electro mechanical care agencies
3. Holistic enhancement in hip replacement
4. Relaxing Healthy Skin Treatment
5. Using Gamification principles to create high value engaging retail concepts and brand experiences
6. Security checkpoints at Amsterdam Airport Schiphol
7. KLM boarding 2015
8. Sustainable Catering Solutions


*Figure 2. The design project topics and an overview of findings from DCS student report topic nr.1*

To summarize, the *barriers* for the use of the CoC in student design projects are: (1) language & definitions; in the design discourse terms such as 'production' and 'representation' are easily misinterpreted, (2) for open design briefings and specific topics it is difficult to use the CoC: existing cultural artefacts are needed as a starting point; (3) some design students loose themselves in specifying the exact relationships between the elements (the meaning of the arrows); (4) the model does not support designers to translate findings into design opportunities; (5) the model does not provide a lens to look at what is cultural (distinction with what is personal or universal); (6) a method or recipe to use the model is missing, and (7) the Walkman as an illustration is perceived as out-dated.
The *opportunities* are: (1) the model supports the discussion about culture in expert meetings, it makes students aware of the complexity of the meaning giving process and the possibilities and limitations of the designers' influence; (2) the model helps to ask culture relevant questions, to set up a cultural study and to structure and report findings; (3) the outcomes help the design students to form a solid base for design and they contribute to the development of their personal design vision and ideas; (4) the model helps educators to check if the students understand the concept of culture.

## 5 CONCLUSIONS: SO WHAT AND WHAT NEXT?

This paper presented a search for doing a cultural study in the context of a design project. How can design students learn to do a cultural study that is meaningful for their design project? We used the Circuit of Culture as a central model.
Despite the found barriers, I conclude that the overarching Circuit of Culture indeed supports design students in doing a cultural study in the context of a design project. The model provides a good view on the phenomenon culture, its complexity and how contemporary cultures can be studied, providing an overview and structure of all the processes that influence cultural change. However, the study also shows that design students have some difficulties to use the model. Therefore, extra attention should be paid to the following. (1) First of all the definitions of each process and the interrelationships should be well explained, illustrated with -preferably contemporary- examples. (2) Then, a method or possible procedure should be developed that help to carry out a cultural study, paying attention to the development of guidelines to set the boundaries of the study, to develop culture specific research questions and to set up the study. The procedure should also be accompanied with design research methods, such as observation, artefact analyses and commercial studies. (3) Furthermore, It would be helpful if the model goes with some guidelines to determine and demarcate the cultural study in such a way that it contributes to the project assignment, including 'global' ones. (4) If we use the model, also examples need to be provided that show how insights from a cultural study can contribute to the development of a design vision or design goal and to a reflection on design concepts. Students should understand that insights from a cultural study do not lead to single conclusions, but that the insight especially can be used for inspiration, to develop one's own stance and to be able to reflect on the cultural impact of their design in a later stage of the project. (5) Since the model especially points out the processes to study culture and not so much the lens that help to look at what is typically cultural, I

suggest to incorporate socio-cultural dimensions. Since our student designers are used to look at the world from a more ergonomic perspective, paying attention to utilitarian values, some extra effort needs to be made to help them to look at cultural values. The socio-cultural dimensions, that I propose in another paper [12] aim to help designers to sharpen that 'cultural lens'. The socio-cultural dimensions, based on anthropological studies, address those topics in human relationships that typically differ from culture to culture, for example, how people cope with hierarchy, how people cope with individual identity or gender roles. The dimensions steer the designer in a way of looking and questioning that is culture specific. (6) Design students -in the context of the here discussed course- should be discouraged to use the model as a checklist and keep them away from a mathematical use of the model. (7) Finally, the model should be used to discuss the designers' influence on culture and society. The CoC may show them limitations; nevertheless, we could encourage them by showing the opportunities that elicit from a good understanding of culture. A cultural conscious approach in design can be useful for various reasons and that is what we need to show them.
This paper presents one way to do a cultural study in the context of a design project, using the CoC. The model places great emphasize on the influence of processes, such as 'Representation' and 'Production' that apply for late-modern societies. However, these influences are less strong in parts of the world -and for the majority of the world's population- that are less developed. That might explain why designers, doing projects in these contexts, often follow a user centred approach. To what extend the CoC is useful in these contexts should be further studied. For now, it seems appropriate to further improve the application of the CoC in a cultural study in the context of our ACD courses.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# THE DIFFERENCE IN COMMUNICATION BETWEEN ARCHITECTS AND ENGINEERS AND THE EFFECTIVENESS WITHIN INTEGRAL DESIGN

**Wim ZEILER**
TU Eindhoven, The Netherlands

**ABSTRACT**
Traditionally the conceptual building design phase is dominated by the architect. However, due to the clear need for more sustainable solutions, building design is being transformed to a multi-disciplinary design team process. However just putting all the different disciplines together right from the beginning is not enough. Therefore a supportive conceptual design method was developed in cooperation with the Dutch professional organizations of architects and consulting engineers. After testing the method through workshops in the industry the method was applied at the department of architecture by masters students in their multi-disciplinary master project Integral design. This enables us not only to use the method for teaching, but also to use the workshops to look at specific characteristics. In this research the focus was on the differences in communication between architects and engineers within an integral design setting. It proved that the architectural students had more influence and were more efficient in relation to functions but for solutions there is not that much difference compared to the engineering students. The used analysis method makes it possible to detect teams in which the architects played a dominant role and as a result there was no real multi-disciplinary team effort.

*Keywords: Integral design, architecture, built environment*

## 1 INTRODUCTION

*"One cannot not communicate. Because every behavior is a kind of communication, people who are aware of each other are constantly communicating. Any perceivable behavior, including the absence of action, has the potential to be interpreted by other people as having some meaning."*

*PAUL WATZLAWICK*

Within the building industry there is a clear need for more sustainable solutions, with as ultimate goal energy positive buildings. This makes building design more complex. Building design transfers from a mainly architect led process into a multi-disciplinary design team process to cope with the growing complexity of the design tasks. In these multi-disciplinary design teams as the design of the building evolves each designer investigates and communicates alternative solutions using separate models of the design, using their own representational idioms and use diverse media for transferring design information (Fruchter et al 1996). The communication difficulties that arise often lead to an impact upon quality of the final design and the time required to reach the result ( Fruchter et al. 1996). Good communication between the design team members is crucial (van Nederveen et al 2010, Brunsgaard 2011, Kanters and Horvat 2012). Especially communication problems between architects and engineers might lead to inefficiency (Kanters and Horvat 2012). Design processes in the Architecture, Engineering and Construction industry are as a result under-productive (Senescu and Haymaker 2013). In sustainable building projects many architects qualified their design process as an Integrated Design Process (IDP): the architects mentioned mostly early engagement of engineers in the process as a clear sign of this (Kanters et al. 2014). However, this collaboration in the conceptual design phase was not always easy for the architects: engineers 'spoke another language' (Kanters et al. 2014). A process approach is needed in which the intentions of the different designers are transparently linked to the design team whether architect or engineer. Support for all design team members by supplying information more transparent will greatly enhance the understanding of the design process and the outcome of the combined efforts of the design team members. To structure the process communication between architects and engineering consultants a supportive method is needed based on abstraction of functions and connected solutions.

## 2 METHODOLOGY

A supportive design method was developed in cooperation with the Dutch professional organizations of architects and consulting engineers. The design method provides overview and helps to structure the communication between design team members. The design method is focused on the creation of proposals in the conceptual phase of building design. After testing the method in workshops as part of a training program in industry, the design method was transferred and applied at the department of architecture for master students for their multidisciplinary Master project Integral Design. Characteristic of the method is the intensive use of morphological charts developed by Zwicky (1948) to support design activities and make them transparent in the design process (Zeiler and Savanovic 2009, Savanovic 2009). A morphological chart is a kind of matrix with columns and rows which contains the aspects and functions to be fulfilled and the possible solutions connected to them, see Fig. 1 A. The functions and aspects are derived from the program of demands. Overall solutions can be created by combining various solutions to form a complete system solution combination (Ölvander et al. 2008). For an example of a morphological chart by an architect, see Fig. 1B.

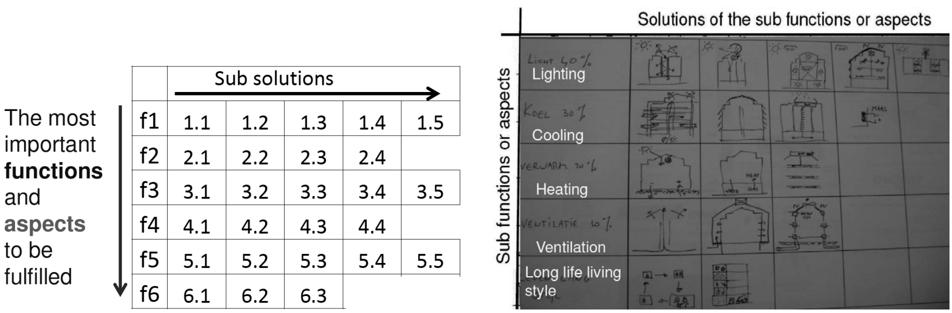


*Figure 1.(A) Concept of a morphological chart and (B) a practical example of a morphological chart by an architect*

The morphological chart (MC) to visualize sub solution alternatives plays a central role in the integral design approach for design teams. Each participant of a design team develops a full morphological chart from their own specialist point of view. These individual discipline based morphological charts can be combined to one overall morphological chart, called morphological overview, by combining in two steps. First functions and aspects from the individual morphological charts are discussed and the team decides which functions and aspects will be placed by in the morphological overview. Then after this first step, all participants of the design team can come up with their solutions for these functions and aspects from their morphological charts to fill in the rows within the morphological overview. Putting the morphological charts together enables to 'put on the table' the individual perspectives from each discipline about the interpretation of the design brief and its implications for each discipline. This supports and stimulates the discussion on and the selection of functions and aspects of importance for the specific design task.

Within the methodical design procedure there is a combination of a first individual process and a second team process. In the first process step each design team member forms his own morphological chart representing his own disciplinary interpretation of the design brief. This followed by a second process step in which the individual interpretations are discussed and the design team as a whole their interpretation as a team about the program of requirements formulates, which forms the basis for the morphological overview. As such the use of the morphological overview helps the individual designers to form a design team with a share interpretation of the design task. After extensive experiments with different set ups for implementing the Integral Design approach, in which well over one hundred professionals participated (Savanovic 2009), it was concluded that the design method was supportive for professionals in the conceptual design phase.

## 3 EXPERIMENT

In the last four years each time a Master Projects Integral design was held in which each year 6 teams of 4 students from different disciplines participated: architecture, structural engineering, building physics and building services. The location and the type of building of the design brief changes every year but the goal of the design project remains the same: to design a net Zero Energy Building. The Master project starts with a workshop of two days with design tasks which were on the same level of complexity and had been used in or were similar to the ones of the professional workshops (Savanovic 2009).

During the workshops sessions in the Multidisciplinary master design projects from 2011-2014, students in multi-disciplinary teams performed different design assignments Central element of the Integral Design process is the use of morphological charts by individual designers which were combined into one morphological overview by the design team. This enabled to compare the results of the architectural students with those of the engineering students

## 4 RESULTS

The generated average amount of functions and proposals mentioned in the MC's and MO's of the session with teams of four students are shown in Fig. 2 and the average result of the students were compared with those of the professionals from the research of Savanovic (2009).

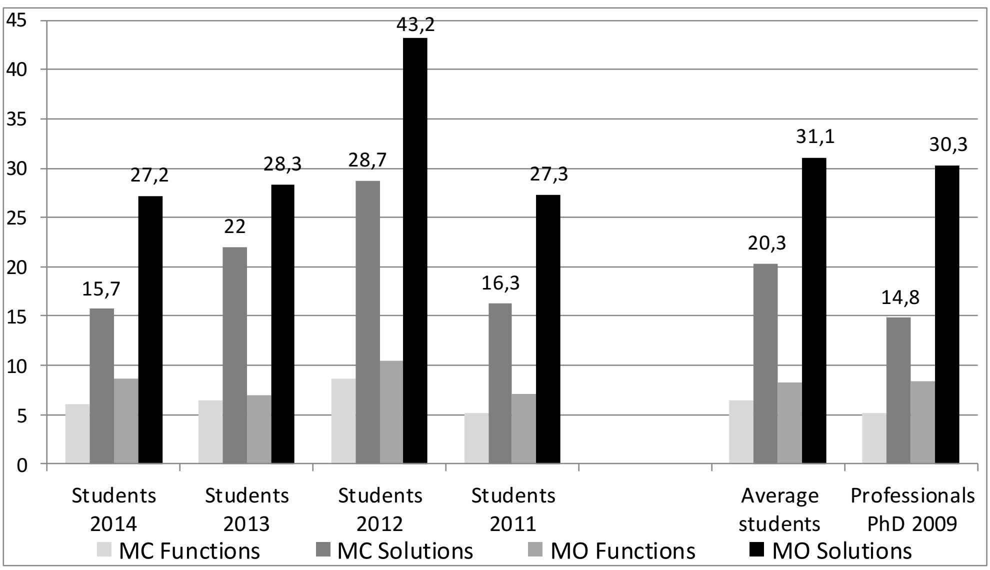


*Figure 2. Number of generated functions and solutions as mentioned in the morphological chart (MC) and morphological overview (MO)*

It showed in all cases that there is an important increase in the number of generated solutions as well as a small increase in mentioned functions when we compare the individual morphological chart with the morphological overview. The teams of architects and engineers together generate significantly more than just the individual team member alone. With the exception of the student from the 2012 workshops the results are quite simular.

Besides the changes in the number of mentioned functions and proposals, we were interested in the influence of especially the students of architecture on the outcome of the design process, in this case the morphological overview. Therefore the number of functions mentioned by each professional in his morphological chart were counted and checked how many of those were finally put into the design team's morphological overview. The same was done for the notated proposals. Based on these numbers the effectiveness of the archtectural students were defined in a percentage: number of functions/proposals as mentioned by the students from architecture, divided by the total number of functions or proposals mentioned in the morphological overview, see Fig. 3. The results are shown of the 18 different teams from the MIO project series 2012-2014, number 19 is the overall average of the architectural students.

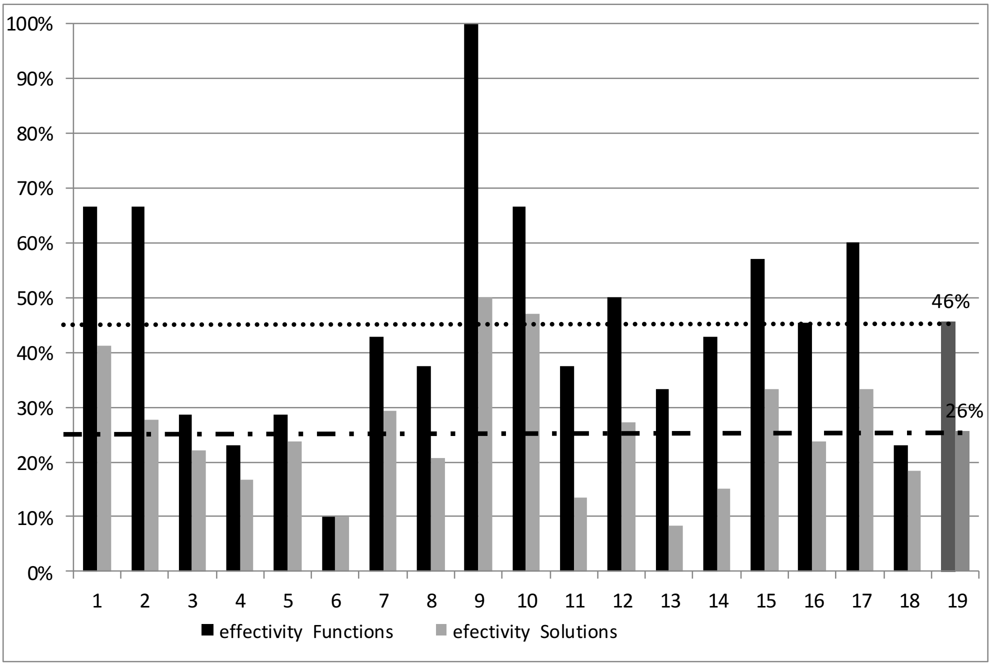


*Figure 3. Percentage influence of by an architectural student mentioned functions or solutions related to those mentioned in the morphological overview*

It showed that the architectuaral student who had a higher than average percentage of influence for the function in general also had a higher influence for the mentioned solutions. Overall the influence of the architectual students concerning functions (46%) is quite high compared to that for the solutions (26%) which is nearly an equal share within the design teams existing of 4 students.

In the next step the effectiveness of the professionals in the design teams was examined. The effectiveness was defined as the number of mentioned functions or proposals in the morphological chart of a professional, in relation to the number of functions or proposals that were notated in the morphological overview of the design team. Based on these numbers the effectiveness of the architectural students were defined in a percentage based on the number of functions/proposals mentioned by the archtectural student divided by the total number of functions or proposals mentioned in the morphological overview, see Fig. 4. Here it showed that in some cases the architectural student was maximal effective (100%) for the mentioned functions. Overall the average percentage was quite high with 51%. The effectiveness of the solutions was with 30% also higher that the expected average between all disciplines. As can be seen there were quite remarkable differences in outcome between the different teams: effectiveness function (between 100 % - 15%, see Fig. 4) and effectiveness solutions (between 70 – 8%, see Fig. 4))

A comparison was made between the way of communication (words, sketches or a combination of both) of architectural students and the effectiveness of the communication by looking at the proposals that were accepted by the design team, see Fig. 5.

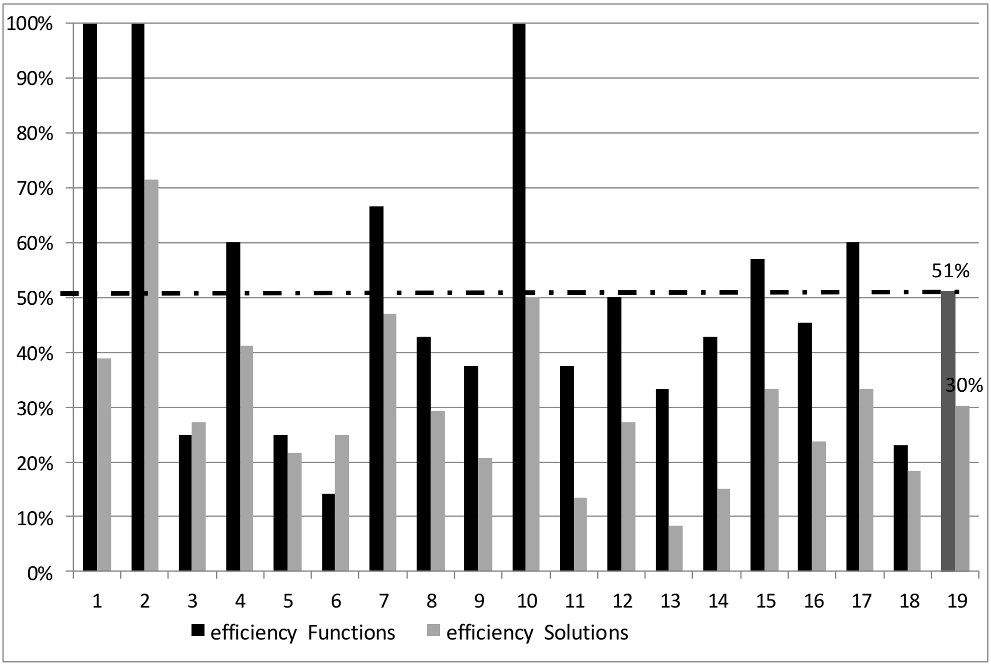


*Figure 4. Effectiveness of an architectural student*

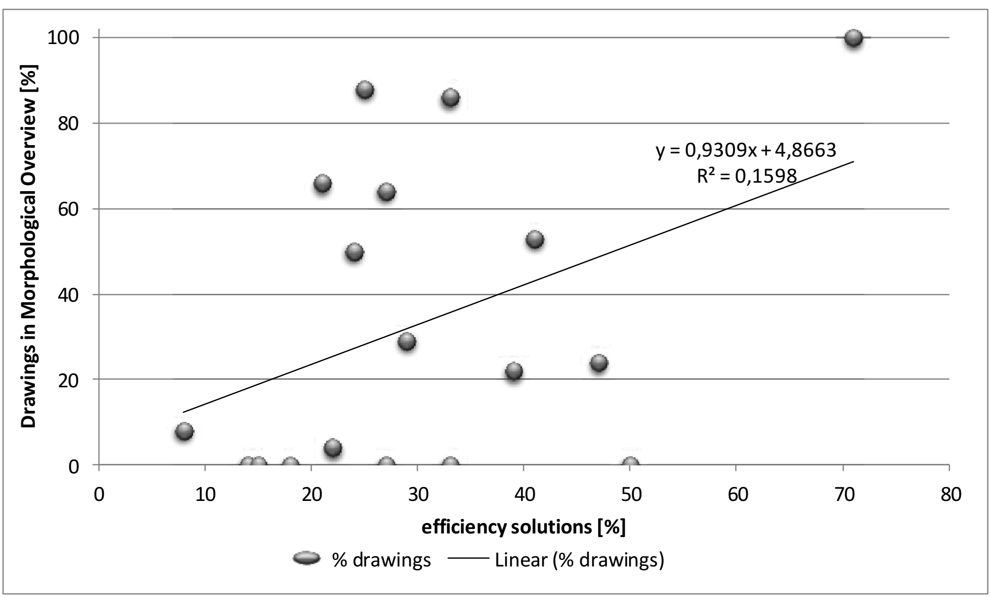


*Figure 5. Ratio between the percentage drawings in the morphological charts of the architectural students and the efficiency of their mentioned solutions*

## 5 DISCUSSION AND CONCLUSION

The integral design method provides overview and helps to structure the communication and reflection between design team members. The application of the design method was focused on sustainability and the creation of new sustainable solutions in the conceptual phase of building design. In the last ten years each time a Master Projects Integral design was held in which altogether in total around nearly 200 students participated from 5 different disciplines: architecture, structural engineering, building physics, building technology and building services.

Important aspect of the workshop is a two-day workshop as a start-up for the project. The set-up of the workshops made it possible to compare the role of the architectural students and the engineering students within the workshops, their effectiveness and the way they were communicating through the provided tool during the workshops sessions: the morphological overview.

In this research the focus was on the difference in communication between architectural and engineering students as representatives of their disciplines within an integral design setting. By using the tools from the integral design method, morphological charts and morphological overview, the conceptual design phase can be made transparent and be studied in detail. It showed that the architectural students communicate in a more influential and efficient way in relation to functions. However for solutions there was almost no difference when compared with the result of engineering students. The use of drawings and words in the morphological charts was slightly more effective than using just words.

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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# FOSTERING PROFESSIONALISM

**Colin LEDSOME**
IED Council Member

**ABSTRACT**
The professional instinct isn't easy to instil in inexperienced students in any field. In sport, to be professional means being good enough to be paid to take part. Professionalism, in most careers, requires expertise of a standard acceptable to other members of the profession, and that each individual accepts responsibility for the results of their decisions.
Professions are usually overseen by membership bodies, which act to define and maintain standards. They also have a learned society role in holding conferences and publishing journals and papers. In some fields, being a member of such a body is a legal requirement in order to have a licence to practice. Except in certain specialist roles, designers have no current legal requirement to belong to a professional organization in the UK. However, there is legislation which does impose direct responsibilities on individuals and their employing bodies for any unfortunate consequences of design decisions, making membership of a professional body a prudent option.
Undergraduates often have only a vague concept of professionalism and the role of a professional body in setting standards. They have come from a school environment, where passing exams was the measure of achievement, rather than the long term acquisition of knowledge and understanding in applied in a responsible way. This paper will explore the concept of design professionalism and ways of appreciating it for the novice.

*Keywords: Human Technology Relations, Design Curriculum, Project Based Learning, Technological Mediation*

## 1 INTRODUCTION

Education beyond secondary school level can be considered under two headings: those courses which provide further knowledge and understanding of a particular field, perhaps leading on to research or a specialist career in that field; and those which are intended as a preparation for a particular career path often with a range of application. These latter courses are frequently certified by an official body or professional system, which maintains the relevance of courses to currently acceptable professional practice and projections of future need. For particular skill areas, most countries have a system of certificates and diplomas, less analytical than degree courses, which are focussed on application and practice. Degree courses include the deeper understanding of a basis for decision making, with appropriate links to management and business.
Within the design spectrum, the Engineering Council was established by Government in 1981 in response to the Finniston Report, "Engineering Our Future" [1], which focussed on practical application. Although the word "design" was hardly used in the report, Sir Monty Finniston agreed later that the design activity was at the core of their recommendations. As a result of this report, the government set up the Engineering Council as the licensing body for the profession. Engineering qualifications in the UK are comprehensively covered by 36 professional bodies licensed by the Engineering Council to set specific standards for their field, meeting the Council's more general requirements. These include a specific reference to design as a major component of initial professional development.
Their original professional requirement, "Standards and Routes to Registration" (SARTOR), took up the main conclusions of The Design Council's Moulton Report [2] that "all engineering should be taught in the context of design and design should be a thread running through the course." A joint Design Council-Engineering Council was set up in 1989 to add more detail, and their report [3] influenced the early recommendations for Codes of Practice. The relevant statements of competence from this report are given in Appendix A.

In the field of product design, the situation is less defined. There is no equivalent of the Engineering Council, so the various membership bodies each set their own standards. The Chartered Society of Designers, CSD, has had the right to award a "Chartered Designer" title for several years, but, at the time of writing, was still defining the requirements, with the expectation of awarding the title in the near future. More recently the Institution of Engineering Designers, IED, has established the title of "Chartered Technical Product Designer", CTPD, awarded in their own right under their Royal Charter. The IED has accredited product design courses for some years, but has not had a professional title to award. They are setting up a system, based on their engineering experience, to make the title available to their qualifying members. This is progressing towards final approval by the Privy Council later this year.

Other countries have their own professional systems, which have evolved historically in different ways. A variety of international agreements are in place to allow professional qualifications to be recognized across borders, even though the methods for obtaining them may vary considerably.

## 2 DEFINING PROFESSIONALISM

Professional bodies usually define professional behaviour through a "Code of Practice" or "Code of Conduct". Although often used interchangeably, these terms have slightly different meanings. The first implies a responsible attitude to the methods of applying professional expertise; while the second refers to the underlying motives and behaviour of a professional. However expressed, the results should be similar. The content and interpretation of these codes changes as new thinking generates a different emphasis. For example, in recent years an additional priority has been give to environmental responsibilities as the effects of global warming have become more apparent.

The Engineering Council's UK-SPEC [4] guidance on Codes of Conduct for engineering professional bodies reads:

Codes of Conduct should oblige members to:

1. Act with due skill, care and diligence and with proper regard for professional standards.
2. Prevent avoidable danger to health or safety.
3. Act in accordance with the principles of sustainability, and prevent avoidable adverse impact on the environment and society.
4. Maintain and enhance their competence, undertake only professional tasks for which they are competent, and disclose relevant limitations of competence.
5. Accept appropriate responsibility for work carried out under their supervision.
6. Treat all persons fairly and with respect.
7. Encourage others to advance their learning and competence.
8. Avoid where possible real or perceived conflict of interest, and advise affected parties when such conflicts arise.
9. Observe the proper duties of confidentiality owed to appropriate parties.
10. Reject bribery and all forms of corrupt behaviour, and make positive efforts to ensure others do likewise.
11. Assess and manage relevant risks and communicate these appropriately.
12. Assess relevant liability, and if appropriate hold professional indemnity insurance.
13. Notify the Institution if convicted of a criminal offence or upon becoming bankrupt or disqualified as a Company Director.
14. Notify the Institution of any significant violation of the Institution's Code of Conduct by another member.

All of the professional bodies holding Engineering Council licenses base their individual codes on this. Product design bodies could be expected to adopt equivalent codes. By joining a professional body, a member is agreeing to abide by these codes.

Interestingly, a recent review of the UK National Health Service introduced the concept of a "Code of Candour" covering the need to give patients, and their relatives, a full and transparent picture of the prospects of potential courses of treatment and to involve them more directly in the decision process. An equivalent emphasis on the closer involvement of stake holder groups in the design process might be a future development of designer responsibilities.

## 3 INTERPRETING THE CODES OF CONDUCT

In interpreting the various codes, concepts such as “professional integrity”, ethical behaviour”, “honesty and transparency”, and “long term responsibility” are clearly key to understanding them. This is in addition to maintaining the currency of standards of expertise, which means an enthusiasm for CPD. The pragmatism necessary in design means that compromise is part of professional considerations. However the professional codes cannot be part of the compromise. If no acceptable solution can be found, the reasoning behind the original design concept must be called into question.

The codes require that a professional should maintain a standard of integrity, even if asked to go against their judgement by a client or manager. This puts a requirement on employers to accept that their professional staff have this obligation. Ideally, professionalism, particularly ethical behaviour and a striving for the best solution should become instinctive. It also implies that a professional should be able to rely on other members of the team to apply similar standards.

## 4 LEGAL ASPECTS

In the UK, except in certain cases, there is no general legal requirement, in product design or engineering, to belong to a professional body. However, the Consumer Protection legislation of 1987 places the responsibility for any damage “caused wholly or partly by a defect in a product” on the producer, or importer, of the product (see Appendix B). Any defence to a charge under this act would depend on the producer identifying the suitably qualified person, who made the decision on the design of the feature which caused the damage. The basic defence would be that any other professionally qualified person could have made a similar decision with the “state of the art” at the time. The defence would fail if the person in question was not suitably qualified, usually demonstrated by membership of an appropriate professional body. More recent legislation on corporate responsibilities has emphasized this point, but none of this has been fully tested in court.

Professional responsibility for a decision affecting a product nominally lasts for the lifetime of the product in service. With current developments emphasizing design for the re-use of products or components perhaps several times [5], the question arises as to where responsibility lies if a re-used component fails. Is it with the original designer, or the person or organization that put it back into service? There may be a requirement for records to be kept detailing design decisions, and the reasoning behind them, along with records of manufacture, maintenance and use, in order that end-of-life decisions may be made with more confidence [6]. It is worth emphasizing that the legislation on design responsibility applies across the whole design spectrum.

## 5 IMPLICATIONS FOR COURSES

It is particularly difficult for inexperienced students to appreciate many of the basic aspects of professionalism. However, such concepts are rarely included in any industry based training or experience, where the emphasis is more likely to foster loyalty to the company and its aims. That can inadvertently provide justification for compromising the integrity the profession emphasizes. Therefore it has become more important that professionalism is strongly promoted in the academic phase of initial formation.

One aspect of engineering professionalism falls on the academic staff involved in teaching courses. A young graduate cannot be expected to have expertise in a topic if it was not given sufficient emphasis during their course. Thus subject areas should not simply be included because a professional body requires it, but because without it a graduate will not be fully competent. The course provider, as well as its accrediting bodies, could be criticized if a novice practitioner does not have a reasonably expected competence or the professional attitude to apply it diligently, if there are unfortunate consequences. This applies particularly in engineering courses.

The considered use of factors of safety and risk analysis, along with a full appreciation of the responsibilities of design decisions, should feature as an explicit part of any design course as well as being implicit in all project work. All design students should undertake at least one design project where there is a clear inherent danger in using the product. For example: this may be a simple kitchen device for chopping or slicing vegetables or a complex manufacturing process where operatives work alongside fast moving processes. Projects could involve devising test procedures for extreme operating conditions or to avoid operator error. The layout of controls and instrumentation for safe operation or avoiding operator fatigue provide more options for projects.

One illustrative source of professional practice is the extensive sets of national and international standards. Great care is taken in compiling standards by appropriate experts with a depth of experience in the field under discussion. Draft standards are published for critical assessment before they become active. In the UK, all British Standards are periodically reviewed and updated to keep them current. Most standards do not give the reasoning behind their statements, but they do represent good practice and the advantages of a common understanding. Students should include an investigation of relevant standards as part of their background research at the beginning of a design project. They should also be familiar with the documentation standards [7], which ensure that the results of the design activity are correctly interpreted during the manufacturing process, wherever it takes place.

## 6 NOTE

Although I have drawn on my long involvement with course accreditation and membership interviews for both the IED and the IMechE, and in the preparation of standards for BSI, this paper is a personal view and does not reflect these body's policies.

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## APPENDIX A – Attaining Competence in Engineering Design, 1991

The joint Design Council – Engineering Council report, "Attaining Competence in Engineering Design", encapsulated professional responsibility as follows:

2.1.3 ACCEPTING ENVIRONMENTAL RESPONSIBILITY

*Chartered Engineers should*

- Be able to explore and take into account the interactions between a design, the environment, and the quality of life of those involved in its realization and operation or only incidentally affected by it. (Including predictable accidents and failure modes, and, where appropriate, waste products, noise, and visual aspects, during realization, storage, transport, use, and the ultimate disposal of materials.)
- Appreciate collective and individual professional responsibilities for environmental protection.
- Be familiar with relevant environmental legislation and the likely public and political perceptions of design features.

2.2.3 ACCEPTING PROFESSIONAL RESPONSIBILITY

*Chartered Engineers should*

- Have an attitude of responsibility towards the safety of user's colleagues, employers, and society.
- Possess personal integrity, a responsible attitude towards decisions, and pride in good practice.
- Never consent to incorporate features in a design, which mislead as to its true worth.
- Be familiar with standards and codes of behaviour acceptable to their professional bodies.
- Understand the need to maintain and develop expertise, both for their current task and their future career, by undertaking a programme of further study or training.
- Appreciate the historic and cultural development of relevant technologies and their relation to existing products and market expectations.

Today, a statement on design for further use or material recovery would probably be added to the environmental requirements.

## APPENDIX B - UK Consumer Protection Act 1987 (Excerpt)

2 LIABILITY FOR DEFECTIVE PRODUCTS

(1) Subject to the following provisions of this Part, where any damage is caused wholly or partly by a defect in a product, every person to whom subsection (2) below applies shall be liable for the damage.

(2) This subsection applies to

- (a) the producer of the product;
- (b) any person who, by putting his name on the product or using a trade mark or other distinguishing mark in relation to the product, has held himself out to be the producer of the product;
- (c) any person who has imported the product into a member State from a place outside the member States in order, in the course of any business of his, to supply it to another.

(3) Subject as aforesaid, where any damage is caused wholly or partly by a defect in a product, any person who supplied the product (whether to the person who suffered the damage, to the producer of any product in which the product in question is comprised or to any other person) shall be liable for the damage if—

- (a) the person who suffered the damage requests the supplier to identify one or more of the persons (whether still in existence or not) to whom subsection (2) above applies in relation to the product;
- (b) that request is made within a reasonable period after the damage occurs and at a time when it is not reasonably practicable for the person making the request to identify all those persons; and
- (c) the supplier fails, within a reasonable period after receiving the request, either to comply with the request or to identify the person who supplied the product to him.

(4) Neither subsection (2) nor subsection (3) above shall apply to a person in respect of any defect in any game or agricultural produce if the only supply of the game or produce by that person to another was at a time when it had not undergone an industrial process.

(5) Where two or more persons are liable by virtue of this Part for the same damage, their liability shall be joint and several.

(6) This section shall be without prejudice to any liability arising otherwise than by virtue of this Part.

# PRODUCT DESIGN EDUCATION: DIFFERENT PERSPECTIVES

**Christopher John CONNOR[1] and Mark BECKWITH[2]**
[1]Northumbria University, United Kingdom
[2]Teesside University, United Kingdom

**ABSTRACT**
This paper explores the differing approaches and experiences of two tertiary level courses provided by two UK University providers within the Product Design subject area. Both institutions provide quite different learning experiences for the students on their courses, both deemed valid in their own right. These differences include syllabus content and delivery, learning environment, to assessment methods. Exploration of student experiences, expectations and aspirations are compared and contextualized in the light of both of these different approaches, one rather engineering biased, the other more creative design focused. Graduate quality from both courses is high, valued by industry and validated by published data on graduate employment rates and roles as provided on behalf of the UK government/Higher Education Authorities. High Employment or further study rates support the assertion that both courses are valued and contribute enormously to the employability of the students undertaking these courses.

*Keywords: Design education, design culture, graduate employability*

## 1 INTRODUCTION

The academic subject of Product Design is well established and popular amongst students in the UK. Courses in the subject are provided by a huge number of UK Universities and other institutions, and student numbers on such courses are high. There are noticeable differences in the nature of course offered at many of these institutions, and the subject can have significant variation in terms of course content and subject emphasis. This paper relates to two such courses offered at two Universities in the North East of England - both well established but quite different to one another in many respects.

The BSc(Hons) Product Design Technology course at Northumbria University has been running since the early 2000s and was conceived as a joint venture between what was the School of Engineering and the School of Design at the time. Staff identified that an opportunity existed for a new course that sought to fill the void between more traditional Industrial Design courses and Engineering Design courses, by combining elements of both to focus upon educating product designers with an emphasis on the engineering, technology and functional performance elements of products.

The interdisciplinary design course was further validated in its early years by the publication of the Cox Report [1] which emphasized the importance of design to the UK economy, identifying that "Design" spans the gap between "Arts" and "Hard Sciences" and made particular reference to the importance of design education and the impact it can have upon subsequent design employment and economic growth. The multidisciplinary approach to design involving business, creativity and design and engineering and technology in order to enhance business competitiveness and development was identified as crucial.

The development of this course, and issues relating to integration of engineering design and industrial design disciplines into a coherent, engineering and technology focused product design course have been covered previously, highlighting issues in relation to course content and delivery, graduate skills and impact upon future careers [2, 3].

The BA/BSc(Hons) Product Design course at Teesside University is well established and has been evolving from the 1970's. It has seen several changes in this time but remains essentially a creative design focused course that has resided within the Arts/Design Faculty, in its various guises, for its entire duration. It is a course that is popular with students and has developed good links with industry during its operational lifetime.

## 2 DIFFERING APPROACHES

There are however, marked differences in approach to the subject of Product Design across these two courses, although both offer BSc(Hons) qualifications upon completion. These manifest themselves in a number of ways, from facilities, to teaching and assessment methods, to display of final year project work.

The BSc(Hons) Product Design Technology course at Northumbria University is offered by the Faculty of Engineering and Environment, whilst the BA/BSc(Hons) Product Design course at Teesside University is provided by the School of Arts and Media.

The focus of both courses is quite dissimilar – Northumbria places its emphasis upon educating product designers in the technical and engineering solution of design problems, whilst the Teesside course focuses upon the creative exploration of design solutions. Whilst some importance is placed upon functional, structural and operational user satisfaction it is not to the same extent as the Northumbria course, which thus perhaps loses some of the more artistic and explorative elements.

The Northumbria course makes significant use of engineering modules and content in its syllabus, in an effort to draw upon the expertise of staff and facilities available. In contrast, the Teesside course has higher ratios of staff that are more creative and industrial design educated. The Northumbria course thus includes many elements of materials testing, manufacturing theory and mechanics in the curriculum. The course seeks to educate students in being able to provide technically feasible design solutions, which can be proven to be appropriate in terms of product structure and function. The Teesside course, whilst recognising the importance of such issues, does not cover them to the same extent, instead encompassing more of the traditional industrial design elements such as aesthetics, user expectation, and presentation.

These two approaches manifest themselves in many ways. For example, as a result of incorporating engineering modules into the course, Northumbria students experience formal examinations as part of their assessment process, whilst more usual design assessment methods such as presentations, portfolios and critiques make up the entirety of the Teesside course, with no written examinations. These examinations only make up a small part of the Northumbria assessment model, where a mix of assessments are used across the various modules that form the course, but it is still a noticeable difference between the two in terms of student expectation and their experiences.

The two cultures across both Faculties have marked differences. Teesside strives to foster a feeling of creativity and exploration, whilst Northumbria tends to put more emphasis upon a scientific approach in reaching solutions and resolving design problems. This is evidenced in the facilities afforded - Teesside provides dedicated design studios, where the students can form a home and an attachment to their surroundings and projects, whilst Northumbria provides no such dedicated facilities for its product design students. Instead, a number of open-access, flexible working spaces are made available to all students within the Faculty. Whilst the benefits of design studios and the learning culture they can engender is well documented and debated [4, 5], the Faculty have deemed that the opportunity to mix with students from other courses outweighs the advantages afforded by residence within a dedicated studio space. The ways in which content delivery takes place duffers; Northumbria makes significant use of theoretical engineering content, which is predominantly delivered through a lecture and support seminar model of student-staff contact. Teesside make much more use of open ended design brief content, and consequently more contact is studio located, discussion based and experiential in nature, exploring more immersive design projects simultaneously.

The two courses also have differentiation in the way they present the graduate student output and final year work, principally based upon the different cultures of the two departments that they reside within. The Northumbria course places great emphasis on students being able to demonstrate technical viability of their solution rather than simply appearance. As a result, their major project presentation models are often more technical demonstration pieces than complete finished model presentations. Teesside meanwhile expects more traditional industrial design displays, with well finished models representing the finished product rather than placing importance upon explaining complex internal features or working principles, although some form of technical evaluation is required in a report Both courses make use of similar levels of CAD renderings and exploded component diagrams to supplement any physical artefacts, but at Northumbria more emphasis is put upon proving aspects such as component interactions, kinematics and structural integrity. The course at Teesside puts more value upon aesthetics, product context and use, and issues such as product branding and user esteem and appreciation, and whilst construction and manufacture are important, they are not explored to the same level as at Northumbria.

The ways in which the two courses present these final outcomes to the wider world, be they other staff and students, industry and potential employers or other interested parties also differ significantly. Teesside display final year work in the form of a show that is organised across the entire school, with many courses displaying their project work. This show has a strong tradition, significant presence and is a major event in the academic calendar, for staff and students alike. By comparison, the Northumbria event is less high profile, instead their faculty show not only encompasses design work, but also showcases research and enterprise activity across the faculty. Teesside then follow up their University design show with displays at the New Designers exhibition in London. Northumbria students instead have the opportunity to showcase their work across the globe by participation in a multinational design show hosted by a partner University in another continent, which displays final year student work from a number of countries in the form of both a physical and online exhibition.
Many of these factors and differences can be summarized in Figure 1, which attempts to display some of the spectrum of product design approaches that span the range from BA to BEng type courses.

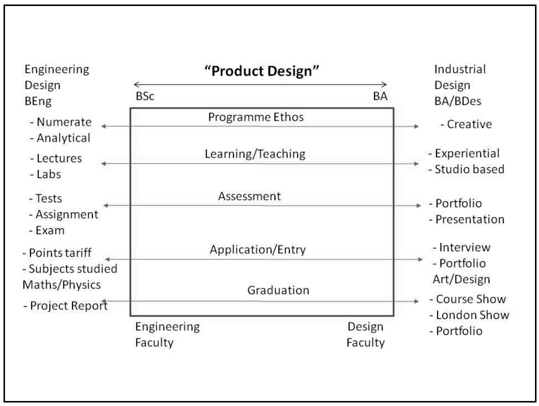


*Figure 1. "Product design" course spectrum*

Figure 1 also highlights some other significant differences. Entry at Teesside typically involves some form of interview and a portfolio of work, whilst the BSc "engineering" approach is based solely upon prior qualifications. In terms of final year work, the Northumbria model revolves more around a report on the major project which covers the technical details of the project, much as a technical engineering design report would, as opposed to the more portfolio natured output typical of the Teesside course outcomes. Although the Teesside students are required to provide some form of technical analysis, it would be expected to contain manufacture considerations rather than aspects such as stress analysis or kinematic considerations, as would be usual for Northumbria students.
There are of course also many similarities across both courses, essential to the core content of a product design course. These include the embedding of themes such as employability, materials and manufacture, design thinking and methodology, ethics and sustainability within the curriculum and course activity of each course. Such requirements and the importance of them to the core education of product designers are well recognized and acknowledged [6, 7]. Both courses teach the basic design cycle, Teesside through many small experiential projects, Northumbria via theory initially before practice. Investment in the student experience in the Northumbria model has focused upon laboratory equipment, analysis software and engineering hardware such as additive manufacturing facilities, whilst Teesside investment is focused around mostly the provision and enhancement of studio/workshop facilities and design software.
There are many aspects of both courses that prepare graduates for employment, and allow them to develop skills and competencies that make them more employable. These include high employer interaction activities, through the use of employer liaison boards to ensure courses are relevant to the needs of industry, as well as embedding design competitions and industrial projects into the curriculum. The courses both teach a number of transferable skills, but using different vehicles and applications to teach similar skills, so for example experiment design is taught in the context of a

scientific investigation at Northumbria, but in the Teesside course it is applied within a design problem context such as to help evaluate user needs.

## 3 OUTCOMES/GRADUATES

Graduates from both the Northumbria University and Teesside University courses are considered knowledgeable, skilled, well rounded and valued by industry. Gathering hard evidence on destinations and the future career paths and movements of graduates is difficult, but some important data is available from the UK Government as part of their efforts to provide University applicants with information related to their potential course of study. This "Key Information Set (KIS)" data includes information gathered from the "Destination of Leavers from Higher Education (DLHE)" survey, which surveys students six months after gaining their qualification from University/College, and also that from the longer term "Long DLHE" which surveys a sample of DLHE respondents a period of 40 months after they left University/College. This information is publicly available via the Unistats service [8]. The DLHE survey seeks information from those recent graduates about their current activities and whether they are working, studying, or seeking employment amongst other things. Those graduates that are in employment are then enquired as to the nature of their role and the kind of employment they are in, as well as their salary. The DLHE survey classifies roles according to the Standard Occupational Classification 2010 (SOC2010) system [9], and includes classification ranges; 1 – Managers and Senior Officials, 2 – Professional Occupations, and 3 – Associate professional and technical occupations; within what it terms "professional or managerial jobs" as provided by the Unistats data. The use of such data in evaluating and comparing courses is limited, but it can provide some interesting information that can be used to feed back and help shape course content and delivery.

The KIS data published provides some encouraging data relating to the employability and nature of roles and organizations that graduates progress to. Both courses have good overall rates of employment or further study, at 87% for Northumbria and 77% for Teesside. These values compare well with others in the sector, and exceed those values for many other courses available.

When considering the question as to whether these graduates are employed in "professional or managerial jobs" six months after graduation, figures of 85% for Northumbria and 57% for Teesside are declared. Whilst this may appear at face value to be a significant difference, some of this variation may be explained by the nature of employment stated by those graduates, and different perceptions as to what role qualifies as being in the SOC2010 classification ranges 1 to 3.

With regard to salaries, discrepancies between the courses could again be due to the initial destinations of graduates, with those progressing into engineering roles (typically Northumbria graduates) gaining higher starting salaries as is more usual within this employment sector where skills can be more readily evidenced than the design sector where it may take longer to establish a reputation and demonstrate competence in this field before higher remuneration results. The average salary of the Northumbria graduate is £25000 (typical salary range £20000-£27000 based upon 25 respondents) six months after leaving their course, whilst the average for Teesside graduates is £15000 (typical salary range £12000-£18000 based upon 35 respondents). These compare with stated averages across the sectors of £25000 (typical range £21000-£28000) and £15000 (typical range £13000-£18000) – different sector averages being stated due to the category each course is categorised into – "Engineering and Technology" for Northumbria and "Creative Arts and Design" for the Teesside course. This demonstrates that both courses are in line with expectations in terms of similar courses within their subject area, whether they be considered to be competing with engineering or creative design type courses elsewhere.

In terms of long term salary expectations, there are noticeable differences between expectation in the engineering and design sectors, with averages of £30000 (range £25000-£34000) in the engineering sector and £17000 (range £16000-£23000) in design roles, 40 months following graduation.

These employment destinations and the impact of average salaries between graduates of the two courses can be seen in Table 1 which shows the most common jobs as identified by those graduates in employment from the available KIS data.

Whilst this KIS data is only valid for the recent academic year and relevant 40 month period, staffs at both institutions consider it a fair and valid reflection upon employment rates and trends, with slight but not significant variability in year on year differing student groups and economic situations.

Less quantifiable evidence also exists regarding the demand for graduates from these courses, in the form of alumni and informal contact data such as communication via social media. These sources provide some destination information regarding graduate destinations and subsequent career movements. Graduates from both courses have very recently progressed to Dyson, in technical engineering design roles, and many other engineering/design companies in the UK and beyond.

*Table 1. "Most Common Jobs"*

| NORTHUMBRIA | % | TEESSIDE | % |
|---|---|---|---|
| Engineering professionals | 45 | Design occupations | 30 |
| Managers, directors and senior officials | 15 | Sales occupations | 16 |
| Business and public service associate professionals | 10 | Elementary occupations | 16 |
| Sales occupations | 10 | Business and public service associate professionals | 7 |
| Elementary occupations | 10 | Managers, directors and senior officials | 5 |
| Business, research and administrative professionals | 5 | Engineering professionals | 5 |
| Science, engineering & technology associate professionals | 5 | Information technology and telecommunications professionals | 4 |
| Design occupations | 5 | Teaching and educational professionals | 4 |
| Administrative occupations | 5 | Administrative occupations | 4 |
| ---------- | --- | Customer service occupations | 4 |

## 4 DISCUSSION

There is no doubt that both courses demonstrate good employment rates following graduation, but some of these issues are worth further consideration and investigation.

One such point is the fact that Northumbria graduates appear to be far more likely to be employed in engineering roles than their Teesside counterparts, who are conversely more likely to be employed in design roles. This may not be quite the case though, and the way in which the respondents classify their employment may be a contributing factor in this misalignment. If the role was an "engineering designer", would this role fall within the engineering role classification or the designer? The answer to this subjective question may depend upon the background of the respondent – discussions with existing students at the two establishments suggest noticeable differences - the Northumbria students more likely to classify such a role as within the more familiar to them "engineering" category, whilst Teesside students are more likely to consider it still being within their "design" field. Similar issues exist in terms of the organization employing them – Northumbria students carrying out design roles in an engineering organisation would be more inclined to classify such as engineering, whilst the Teesside students suggested they would still classify it as design role, albeit applying it to an engineering environment.

Discussion with students at both establishments reflect and reinforce these perceptions, with Northumbria students being far more receptive to engineering careers, whilst Teesside students are keener and more intent on trying to find employment in the design sector. These factors would support the results from the data in respect to the different employment destinations reported. Several Teesside students indicated that they would be less likely to consider engineering type roles, and they feel that their strengths lie in researching design problems and producing an innovative initial solution. Northumbria students highlight the engineering development of an outline concept as their strengths.

The data presented appears to be an accurate reflection of the employment trends across the sectors concerned, where investigation into other University statistics reflects similar results. Other UK institutions offer both BA and BSc Product Design courses, and the outcomes from the establishment reflect those outlined in relation to the two separate institutions highlighted in this study, with similar disparity in terms of overall employment rate and salary levels, as well as inequalities in areas of employment between the two courses. One interesting development being considered is cross course projects, allowing cross-fertilization of student experience and potentially opening up new employment avenues for each group.

There is evidence that both of these approaches can produce well rounded, capable product designers as shown by the ability of students from both of these courses to win prizes and awards at National and International design competitions. Several national awards have been won by students from both courses reinforcing the belief that both can provide students with the necessary skills and learning opportunities to compare well with other students at other Universities throughout the UK.

## 5 CONCLUDING REMARKS

This paper has shown that the approach to the teaching of product design in the UK can be quite different depending upon establishment, and can provide students with quite diverse experiences and environments in which to learn and practice product design. It shows that both approaches can be valid, valued and give excellent experiences and employment prospects to students..

Whether the approach is to focus upon the "engineering innovation" of products, or the "creative originality" of them, they both involve some similar elements that provide students with a core understanding of the process of product design and development. The application of such and problem solving skills that students develop as a result make them highly employable and sought after across a variety of design sectors.

Both courses can be seen to be successful in educating product designers, evidenced by graduate employment rates and roles, whilst the differences in content show that there is room for a variety of approaches and specialist focus within product design education in the UK.

This study demonstrates that it is possible for product design courses to employ quite different approaches, emphasizing either engineering or industrial design aspects, and both provide vibrant, engaging learning experiences that prepare students well for future employment in the engineering or design sector, or both.

The authors recognize that this "snapshot" of data represents only limited insight into the future careers of graduates and the relative success of each course in preparing students for employment, and future work is planned into investigating the longer term trends associated with such data. Further work into evaluating the perceptions and aspirations of students with regard to engineering or design roles following graduation is also planned.

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# CULTURALLY INFLUENCED LEARNING: WHY DO SOME STUDENTS HAVE DIFFICULTIES VISUALISING IN 3D?

**Mark MILNE, Richard MORRIS, Tim KATZ, Derek COVILL and Eddy ELTON**
University of Brighton, United Kingdom

**ABSTRACT**
This study is a continuation of a developing interest in the observed problems of a group of engineering students undertaking a first year BEng course in Mechanical Engineering, and in particular a module in Computer Aided Engineering and Design. A previous study had noted that some students arrive on the engineering course with a range of abilities in drawing and 3D (spatial) visualisation, and that these difficulties can be a significant barrier for progress. Other studies have shown that spatial visualization is a significant predictor for success on engineering courses, and that the ability to visualize objects, forces, moments and effects on physical bodies is vital to the development of core engineering skills. A significant number of students on the course are from overseas, and during the initial study it appeared that these students were more prone to experience difficulties in spatial visualization, as measured using a standardized test. Methods were evaluated to help these students improve, and these proved successful. This paper presents the latest results from the continued study, which explores a hypothesis that earlier learning and exposure to drawing, both Art and engineering, influences core spatial visualization, and that cultures which focus on traditional mathematical and science skills, may create issues for some students with respect to spatial visualisation. The study also incorporated analysis of a group of Product Design students with a very different profile in terms of their exposure to Art and drawing and their cultural background, as a means of providing contrast to the initial study.

*Keywords: improving spatial visualisation, 3D visualisation, culturally influenced learning, education*

## 1 INTRODUCTION

### 1.1 Importance of spatial visualization in Engineering

Tertiary education in engineering focuses to a large extent on the development of core analytical skills, and therefore selection for these courses relies on evidence of a knowledge and aptitude in the mathematical and physical sciences. Course selection does not generally specify any requirements in drawing or even specific engineering or technical drawing skills. Only if Design is featured as a major course element is there perhaps any specified need. However, there is significant evidence that an ability to visualize objects in 3D, and relate these within a spatial framework is vital to the development of engineering skills. Sorby states that “Researchers have found that 3D spatial skills are critical to success in a variety of careers, particularly in engineering and science” [1], and more specifically “spatial visualization or the ability to perform complex mental manipulation of objects has been established as a predictor of success in several technology related disciplines” [2].

How can engineers correctly apply their mathematical modeling skills in the physical world, if they struggle to correctly visualize the complex multi-dimensional problems they encounter? Spatial visualization (S.V.) is the term applied to the ability to create accurate mental models of the physical world. It is this skill that allows humans to imagine the relationships between objects, predict changes and movement and dependencies, as well as relate their position within their environment.

### 1.2 Prior research – The previous study

An initial study was carried out to investigate observations that some students on a first year Computer Aided Engineering and Design course, within a Mechanical Engineering degree at the University of XXXX, had significant problems with visualizing objects, particularly when creating orthographic drawings of engineering components. It was not clear why these students struggled to be able to correctly relate the features within the objects and draw these in 2D planes correctly.

The class of 140 students had a significant overseas component, mostly from the Middle East and North Africa (MENA). It appeared that most of the observed problems were from this group of students.

At that stage the focus was on identifying ways of measuring their core spatial skills and techniques to quickly improve this as a means of removing this barrier to successful course completion. It had been observed that some students in previous years had indeed continued to struggle, and in fact this represented a major barrier to their overall course progression.

A literature search was undertaken to identify methods for measuring spatial visualization, and also best practice thinking on how to improve this most effectively.

Sorby [3] reported that Gimmestad in 1989 found that the Purdue Spatial Visualisation Test: Rotations (PSVT-R) was the most significant predictor of success in a study conducted at the Michigan Technological University (MTU).

Details of the test were sourced and the class tested using the PSVT-R. A group of students with low scores (lower than 60% threshold) were identified and these correlated well with the students experiencing difficulties with engineering drawing. These students were invited to take part in a voluntary 9 week, 2hr per week support class designed to improve their S.V. ability. The test was also used at three week intervals in order to measure any changes in S.V.

A variety of techniques were tried:

1. Use of a computer software program created by MTU to develop S.V.

2. Using SolidWorks 3D models to explore the relationships between features and orthographic views.

3. A technique developed at the university of XXXX called 'blind sketching', where participants were invited to develop sketches of objects hidden in a bag, and explored only through touch.

The workbook and software was provided by Delmar CENGAGE Learning 'Introduction to 3D spatial visualization an active approach' by Sorby and Wysocki [4].

The students used solid models of three dimensional parts using SolidWorks, exploring these by rotating the objects and creating cross-sections with a series of exercises based on existing solid models as shown in Figure 1 below.

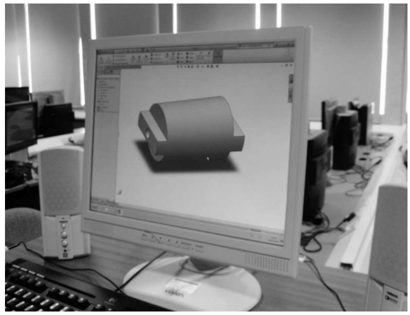

*Figure 1. Exploring 3D using Solid models*

The ‘blind’ test involved students having to sketch a 3D component in a bag (Figure 2), where they were only allowed to explore its features by touch, and therefore construct a purely mental visual picture of the part from which to then draw a series of views.

*Figure 2.*
*Examples of the physical parts for the ‘blind’ sketching exercises*

The Mechanical Engineering class consisted of 116 students, of which 5% were female and 26% from African, Middle Eastern or Asian origin, with the majority of the class from Europe. Of this class, 51 students sat the PSVT-R test and 15 students were identified with a score of 60% or less. These students were invited to take part in voluntary support classes. After three classes the students were re-tested using the PSVT-R and the results shown in table 1.

*Table 1. PSVTR Results*

| **Group** | **Average** | **Standard deviation** |
|---|---|---|
| ME111 whole class (51) | 74.7% | 17.6% |
| Support Group (pre classes) | 53.6% | 12.3% |
| Support Group (3 classes) | 70.8% | 16.0% |

The significant improvement in the support group was similar to studies identified in the literature search where improvements can be seen within similar timescales, and with similar periods of study.

Even with this short period of support study, most of the students showed a significant improvement in PSVT-R score with the average improving from 53.6% to 70.8%. This was compared with other studies as shown below.

*Table 2. PSVTR results from other published studies*

| Group | Pre classes | Post classes | Study |
|---|---|---|---|
| PoN | 52.2% | 63.8% | Ault and John 2010 |
| Purdue | 66.7% | 80.0% | Harris 2009 |
| VSU | 52.2% | 74.7% | Study 2006 |
| MTU | 51.0% | 78.0% | Sorby 2007 |

The study had been a success in finding a reliable method for measuring S.V. and identifying strategies to successfully improve this skill.

It was decided to continue the study in future years to determine if the observation that more of the MENA students exhibited difficulties was valid, and to identify reasons for this.

An observation had also been made that the blind sketching had proved particularly effective. It was apparent that students were forced to mentally visualize the objects, and the same students were observed manipulating the imagined objects. The conversion of students from 'guessing strategies' to imagined mental images (Figure 3), seemed important in developing S.V., and this required further study to identify best practice learning strategies.

*Figure 3.*
*Student 'visualising' an object rotation*

### 1.3 Factors influencing spatial visualization

A number of studies have identified several factors including age, gender, individual differences and experiences that impact visualization ability [5]. Gender in particular is well documented, and the initial research at MTU was in response to a need to develop strategies to improve S.V. for female students. However, research into other factors is less well defined.

The study by Ault and John of a group of Namibian students [6] demonstrated that their appeared to be a significant difference between comparable groups of engineering students in Namibia and their western counterparts in the US. However, there is little available research that explores this further, or any possible reasons for this observed difference. This has now become a focus for continued research at the University XXXX, particularly as the number of overseas students has been increasing in recent years.

### 1.4 Culturally influenced learning

There is a significant volume of research in the cultural differences between Asian and western students. These are described as Confucian and non Confucian approaches to learning, with what is often noted as a more rote approach to teaching and learning in the Asian Confucian cultures. However, Biggs [7], and others [8] [9]have commented that these apparent surface approaches to learning do not prevent Asian students adopting deeper learning strategies, and in fact Asian students are out performing Western students on many courses.

The same level of research does not appear to be available regarding the approaches to teaching and learning in the MENA countries, but there is anecdotal evidence that more didactic teaching strategies are commonly used in developing countries. Cultures with a strong religious teaching element tend to focus on rote learning initially, and there may be some comparison with the Confucian teaching cultures.

Art in the Middle East appears to be a more geometric design activity with less rendered object form.
A hypothesis was formed that developing cultures that required success in engineering promoted traditional subjects such as Mathematics and science, and students had a reduced exposure to drawing and sketching 3D form. This may create a disadvantage for many students with reduced S.V. skills when eventually undertaking an engineering degree.

### 1.5 Engineering and Product Design

Two quite different groups were available for the study. It had already been observed in the earlier study that the average PSVT-R score of the first year Mechanical Engineering students was lower than that of a group of first year Product Design students. There were two observed differences between these groups:

1. The Mechanical Engineering students had a significant proportion of overseas students compared to the almost 100% UK and European Product Design student base.

2. Product Design students are interviewed for the course, and must demonstrate sketching, design and practical making skills for course entry.

### 1.6 Study Objectives

A number of key questions were identified for the study:

1. Is exposure to art, sketching and drawing, including engineering drawing, a positive factor in developing S.V.?

2. If so, is it true that MENA countries do not encourage these skills in their educational systems, favouring traditional subjects such as Maths and Science, and thus disadvantaging their students for more applied subjects, such as Engineering and Design?

3. Is the haptic 'blind drawing' activity more effective in developing S.V. than visual based approaches such as using computer models, and 2D representations of objects as used in training workbooks?

## 2 METHOD

### 2.1 Testing Spatial Visualisation (S.V.)

The various groups of students were tested using the Purdue Spatial Visualisation Test – Rotation (PSVT-R) developed by Bodner and Guay [10]. This test consists of a 30 question multiple choice timed paper (20 mins), where an isometric view of an object is shown in two states, an original position, and after undergoing single or multiple rotations. A different object is shown, and the student asked to select the correct response from five possible answers using the same rotation or a series of rotations. An example is shown in Figure 4. To successfully answer, the student needs to be able to visualize the object in 3D and correctly manipulate this mental image.

The suggested threshold for the test is 60% correct responses, out of the standard 30 questions.

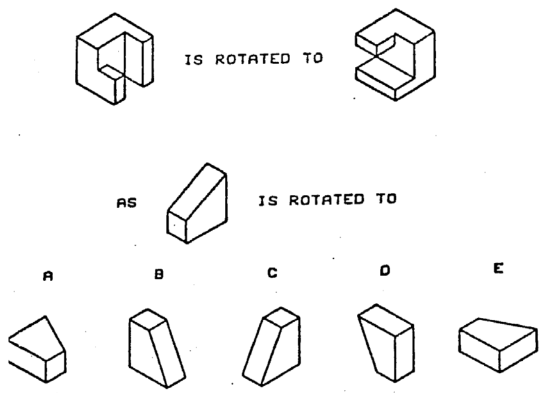


*Figure 4. Example from PSVT-R Test*

### 2.2 The Study

The mechanical engineering students were invited to take part in the study and undertake the PSVT-R test. In addition the students were asked to indicate the countries where they had undertaken their primary and their secondary education. They were also asked if they had received any formal or informal Art, drawing or engineering drawing classes.

The Product Design students from the first, second and final years of their undergraduate degree were invited to undertake the PSVT-R test. The students were also asked about their experiences in sketching and any relevant engineering drawing classes.

## 3 RESULTS

The results from the PSVT-R tests between the groups are summarized below in table 3.

*Table 3. PSVTR results from the latest group studies*

| Group | Average | Standard deviation |
|---|---|---|
| Mech. Eng. – Year 1 | 70% | 19.8% |
| Prod. Des. – Year 1 | 77% | 11.6% |
| Prod. Des. – Year 2 | 75% | 13.2% |
| Prod. Des. – Year 3 | 82% | 11.1% |

28% of the Mechanical Engineering class scored below the 60% threshold and have been invited to take part in the support classes, and investigation into the effectiveness of the various improvement techniques. The lowest score received was 20%. This study is on going at present and no conclusions have been drawn at this point.

This contrasts with the Product Design groups. In the first year group, four students did not meet the threshold (18% of the group) with the lowest mark received at 43%. In year 2, three students did not meet the threshold (15% of the group), with a lowest score of 53%, and finally in year 3 all the students met the threshold score. This does indicate an increasing S.V. ability as student's progress through the Product Design course.

35 Mechanical Engineering students failed the PSVT-R threshold out of 124 students that took part in the study (28%). 15 of these students were from MENA countries, 7 from the UK, 5 from Europe, 3 from Eastern Europe, 3 from Asia, 1 from South America and 1 from South Africa.

## 4 DISCUSSION AND CONCLUSIONS

While the largest problem group are from the MENA countries, the results were not as marked as anticipated, and there were further quite surprising findings. Of the 15 MENA students with low scores, 8 of these indicated that they had undertaken formal or informal classes in drawing or engineering drawing specifically. From the 35 students identified, only 12 of these indicated that they had no previous exposure to drawing or sketching.

Interestingly 27 students scored 90% or greater, and of these 6 students indicated that they had not undertaken any formal or informal drawing classes.

In summary, 34% of students with a score lower than the threshold mark indicated they had no drawing experience, and of the students scoring 90% or greater, 22% indicated that they had no previous drawing experience.

It was also clear looking at students from Kuwait that all had received some formal drawing training, but this group included students with very high PSVT-R scores, as well as students with scores lower than the threshold.

Some further observations were made of Mechanical Engineering students who provided more detail on their educational background and experience of drawing. Two students in the below threshold group were able to show drawing portfolios demonstrating very good sketching skills, and both had undertaken formal Art and drawing classes. In addition, one of the year 2 Product Design students that failed to meet threshold showed evidence of having completed an engineering drawing course including orthographic projection and cut planes.

Further analysis and investigation is on-going, but the results to date do surprisingly indicate that the correlation between drawing and S.V. is not as marked as expected, and it would appear that there are other significant factors involved.

One first year student who entered Product Design as a mature student from industry, and who had previously trained as an electrician wiring houses and Industrial units, scored 100%, This student had not undertaken any formal drawing classes, and his sketching portfolio was weaker than average. His occupation had relied on his ability to relate his position within the building and it's hidden structure, allowing him to feed cable effectively from one point to another.

The observations from the effectiveness of the practical blind drawing activities indicate perhaps that spatial visualization is trained more from actual physical spatial tasks, and while engineering drawing, orthographic projection and a students ability to visualize forces etc. is manifest as a result on paper, or a 2D computer screen, training using drawing or 2D methods to represent the 3D world is perhaps not so effective. It may be that it is not a lack of exposure to drawing or Art that affects MENA students, but rather a lack of practical hands on making or problem solving. Certainly all Product Design students need to demonstrate practical design and problem solving skills within their design portfolio, and it is perhaps student's skills developing in these areas that improve S.V. This is perhaps the reason that S.V. improves as students progress through the Product Design course, where their practical problem solving skills in design are manifest in more complex prototype construction.

The study is now being modified to investigate this further. The desire is that students entering Engineering courses at the university can be tested on entry, and effective practical courses developed to quickly improve this skill before it becomes a barrier to successful progression. The hypothesis has been modified to the reason that students exhibit lower S.V. ability is related to how much practical spatial problem solving they have been exposed to. Practical hands on tasks may build this ability more than any visualization tasks, or tasks that rely on drawing, and the reason that a proportion of overseas students seem to have lower S.V. skill is that their educational experience has been less practical than in other cultures.

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# PRESERVING CULTURE IN DESIGN

**Troy Austin LEININGER**
Brigham Young University

**ABSTRACT**
Technology has created a new culture, a new community - the online community. The ability to interact with a person 8.000 kilometres away has all but dissolved boundaries that once existed. This super-connectivity unifies the human race; but as cultures blend, some aspects are lost. As designers we need to recognize this trend and return to our roots - return to what makes us who we are.
The Cikrak chair by Adrien Garderè, a designer from Paris, is a brilliant example of tying historical or traditional culture to the modern-day context. The chair came from a project on the island of Surabaya in Indonesia and employed a method of weaving that the indigenous people employed to make shovels. Garderè found one way of acknowledging the culture in his design of the chair. If we as designers let culture help inform the product, we will not only create a more meaningful piece but one that celebrates that which makes us unique.

*Keywords: Culture, globalization, design*

## 1 CULTURE AND DESIGN - INTRODUCTION

In his novel *1984*, George Orwell describes a very bleak, grey setting of "the future." The main character Winston Smith lives in a dystopian society ruled by a totalitarian government. The government has complete control over nearly everything in the citizens' lives: where they work, what they eat, when they exercise, even when they give service. The government informs the general population that Oceania, their country, is currently warring against Eurasia. The citizens are forced to participate in two minutes of hate every day in which they decry Eurasia for their faults. However, in a moment's notice, the government claims that they are now at war with Eastasia, not Eurasia, and always have been fighting Eastasia. The public accepts the new information without a second thought. The people do not have access to outside information: books, mail, or Internet. This control over information creates an interesting society. Since all knowledge comes from the same source, they begin to think, believe, and behave the same as everyone else. In short, general public becomes one homogenized mass.

Communication is absolutely key in the formation of culture. Today we are witnessing a massive technology boom. From smart watches to Twitter, our world changes every year. The question is: what is the effect on culture?

## 2 CULTURE DEFINED

Culture is what defines us; it's who we are. "Culture refers to the cumulative deposit of knowledge, experience, beliefs, values, attitudes, meanings…concepts of the universe, and material objects and possessions acquired by a group of people in the course of generations through individual and group striving." [1] This definition of culture mentions a cumulative deposit. This cumulative deposit is a bank in which all contribute. Groups of people grow as a community; it is a give-and-take action. Beliefs are preached, knowledge is passed on to the youth, and experiences are shared. These communities share commonalities that bind them together and it is this that evolves into what we know as culture.

If culture is created from this cumulative pool of shared knowledge and experience, then communication is key, whether it be the oral traditions of Nordic mythology or the hieroglyphics of ancient Egypt. Cultures in the past have been defined partially by whom they were able to communicate with. One basic example is the difference between Europe and the United States. Europe has a much longer history than the USA. Countries such as Italy or France have been around for thousands of years. When they began to be formed, communication was relatively slow whether by foot or horse. When they developed into nations, they became two separate and distinct cultures and languages partly because of the speed of communication. However, in the USA, Georgia and Virginia have a much shorter history. Not long after the colonization of the states, the telegraph was invented. This led to the acceleration in communication and now the two states have similar cultures and language.

Though it is a simple, flawed example, the principle is clear: communication has a profound effect on language. There are numerous articles describing the effect of language and the formation of thought. People gravitate to those whom they feel think or believe similarly. This is evident in many instances, from adolescent grade schools to churches; from political parties to social media. The halls of many American grade schools are filled with the Preppies, the Emos, the Footballers, and the ever-present Goths. And what is a church but a place where people who share doctrinal beliefs commune? So if how we think is affected by language, then it will ultimately affect with whom we interact.

There are also different levels in which one could break down culture: national, regional, corporate or social class. The national level could be French culture. Regional could be West coast. However, with the advancements in technology, there has been a creation of a new culture - the online culture. This culture is a new and very interesting development on the anthropological scene. The ability to interact with a person thousands of kilometres away has all but dissolved physical boundaries. What one person sees on a website can simultaneously be seen by another across the globe. Companies are no longer bound by the small town it occupies but can do business with customers anywhere in the world.

If communication drives culture, then this new method must have some effect on culture. One of the major factors in this change is the source of the information. In pre-Internet days, people learned and observed from their environment. Libraries, professors, and parents were the main channels of information. Long gone are the days where students actually had to use books from the library. The advantage to the pre-internet age is it provided for a strength in and attachment to community. Information was found in the community and thus thought and belief structures were very much connected to those people around themselves. It also formed societies with distinct cultures because their knowledge, experience, beliefs, etc. were independent of their neighbours 100 kilometres away. They had to deal with life using their own methods. With the magnificent invention of the Internet, a new channel of information was created. Suddenly, we no longer were dependent on our geographic community to inform our culture but are affected by the massive online culture. Answers to history questions were found in milliseconds using Wikipedia. Reasons for the Great Depression were discovered on the first page that showed up on Google. Look at any rhetoric class and ask where the students find their sources. You would be hard-pressed to find any student that didn't use the Internet to help inform the subject.

So what is the ultimate effect on culture? The cumulative deposit that used to be found in one's community is now generally found on the Internet. This new deposit is one massive pool from which many people pull information. If we all retrieve information from the same source, we essentially become one community. We communicate in the same manner because we hear and see the same things. As communication helps thought formation, we will begin to think the same. We may even become a shadow of the community of Orwell's *1984,* thinking the same, acting the same. This dependence on the Internet for information could lead to the homogenization of culture.

### 2.1 The Onion Model

In Cultures and Organizations: Software of the Mind [2], authors Geert Hofstede, Gert Jan Hofstede, and Michael Minkov offer some insight into understanding culture. In their "onion" model, they explain the varying depths of culture manifestations.

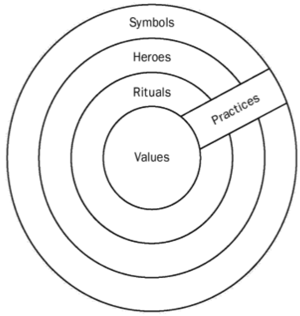


*Figure 1. The "Onion", Manifestations of Culture at Different Levels of Depth*

As explained in the book, the manifestations become deeper and more meaningful the closer they get to the centre of the model. So the deeper the level of manifestation a product incorporates, the deeper it can connect with the user. Symbols are "words, gestures, pictures, or objects" that hold a meaning to a culture. Symbols have short lives; they come and go with time. An example of a current symbol would be the hashtag. The hashtag is the name for the number or pound sign that recently has acquired a new meaning to some current cultures. Let's say there is a product using this symbol - a hashtag waffle iron. This fictitious product would form waffles in the shape of the hashtag. The hashtag waffle iron would likely be treated as a cheap, informal gift meant for a laugh rather than being treated as an actual product. But why? The hashtag has become associated with the current generation of youth; it is a symbol. Symbols, according to Hofstede, Hofstede, and Minkov, are only a shallow representation of culture. The waffle iron doesn't draw from any deeper cultural manifestations and thus it is treated lightly. On the other hand, a product like Adrien Garderè's Cikrak chair attempts to dig deeper.

### 2.2 Example 1

*Figure 2.1. Cikrak chair, Adrien Garderè*

*Figure 2.2. Shovel, traditional Indonesian weave*

Recently, Adrien Garderè visited Brigham Young University to discuss culture and its role in design. Much of his discourse revolved around understanding the importance of the culture in which the product belonged. Essentially, Garderè stated as a designer created a product with the context in mind, the product would be a more meaningful product.

As an example, he described his workings on the Cikrak chair. The chair comes from collaboration between the French Cultural Centre of Surabaya (Indonesia), the University of Technologies in Surabaya, and Garderè. While visiting Indonesia, Garderè noticed an interesting process that was used to make a shovel. The process involved splitting a stalk into fingers and weaving reeds through the fingers to make a basket. Garderè and his team used this process to help create a chair that was later used for the Cultural Centre's auditoriums and classrooms. But the important thing is that Garderè observed and gained insight into their culture. Involving their culture in the design connects the people to the product. The chair, used in Surabaya, pays great respect to the Indonesian culture and history. By doing so, the chair becomes more meaningful. The Cikrak chair is more likely to become a design classic than the hashtag waffle iron because it draws from deeper cultural connections.

Garderè mentioned also the importance of avoiding cliché or shallow connections to culture. Using stereotypical views to attempt to connect to the culture was a poor method. One could use surfboards to make a chair designed for Californians but is that really their culture? Or is it just a stereotype? It is a more difficult thing to really capture the deeper meanings and feelings in a culture; however, when understood fully, one can design something of worth.

### 2.3 Example 2

*Figure 3. PP501 or "The Round One", Hans Wegner*

Many people find Scandinavian furniture to be beautiful or admirable, whether it fits their tastes or not. Why? What is it about Scandinavian furniture that somehow seems to reach to so many people?

Scandinavia was never an easy place to live before the discovery of electricity and the industrial revolution. Long, harsh winters were interspersed with beautiful mild summers. Being so far north on the globe led to very dark winter seasons. Possibly because of these conditions, the people of northern Europe were moulded into a group with distinct, interesting values. Light was an important theme in their culture. Living rooms were designed to be light and spacious, avoiding clutter in order to keep their spirits uplifted during the winters. Bright, colourful accents brought textiles to life to help offset the dark season and to indicate the beauty of northern summers. Wood became the material of choice as it was readily available and had a warm touch as opposed to steel or concrete. These are some of the core values shared by many Scandinavians.

Perhaps one reason people recognize Scandinavian design as among the greatest is the Scandinavians' ability to encapsulate their own culture into their products. One example of successfully accessing these cultural icons or cues in design is Hans Wegner. Hans Wegner's PP501 or "The Round One" utilizes the deepest levels of cultural manifestation, if we use the "Onion model" from earlier.

The use of hand-carved wood rather than machined methods indicates the importance of humanism in products. It also pays respect to the environment by celebrating a material produced by the earth. The warmth that wood provides isn't found in other man-made materials. The overall form of the chair is simple from a distance but complex upon examination. It is also unpretentious, something very typical of Danes. The viewer can see the values of post-modern Scandinavia incorporated into one chair. Perhaps this is why Wegner's PP501 is one of the most respected and appreciated chairs in history; it is more than just a beautiful chair; it connects with people on a deeper level.

## 3 APPLICATION

Understanding this concept should start early in the designers' education. Incorporating the cultural aspect to products should be part of the design process and part of design thinking. It should never become an "after-market accessory", or something that is thrown on in an attempt to create the façade of consideration. As it becomes integral in the design process, the products will naturally inherit the features and characteristics needed to become meaningful.

One example of an exercise that can be employed could be directly based on this "Onion model." Have the students design two versions of the same product – one that only uses the outermost one or two layers of the "Onion" and one that draws from the centre of the "Onion." By controlling other variables, the teacher can isolate the cultural variable. The students will then be able to focus on cultural factors. The intent is to help the students recognize cultural factors and how considering cultural context affects their work.

Another exercise that can be used would be to design to another culture. One branding exercise used at Brigham Young University involved applying a brand to a random product. A spin-off of this type of exercise would be taking another culture and designing a product to that culture. For example, have the students design a toothbrush for a Japanese businessman and/or an Argentinean construction worker. The exercise would help the students immerse themselves in the culture and context of the problem. Beyond showing the students to look outside their own realms of knowledge, it would build empathy and understanding of the user, which would ultimately help inform the product.

## 4 CONCLUSION

The importance of understanding the effect of culture is critical to design education. Students who understand how culture plays a role in our lives will not only create more meaningful products but will contribute more fully to society. There is pressure from owners, leaders, or other managers to pump out ideas and to create fast products. As designers we are the creators of artifacts. We determine what history will remember our communities by - whether through our successes or failures. With the majority of the developed world addicted to the latest and greatest gadget, there is a great homogenization of culture. Unless we find the world painted by George Orwell in *1984* attractive, we need to let culture inform our design. As we do so, we will create a world full of beautiful, diverse design.

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# PROBLEM BASED LEARNING VERSUS DESIGN THINKING IN TEAM BASED PROJECT WORK

**Marianne STOKHOLM**
Department of Architecture, Design and Media Technology, Aalborg University, Denmark

**ABSTRACT**
All educations at Aalborg University has since 1974 been rooted in Problem Based Learning (PBL). In 1999 a new education in Industrial design was set up, introducing Design Based Learning (DBL).
Even though the two approaches have a lot in common they also hold different understandings of core project based learning issues, which has caused a need to describe and compare the two models; in specific the understandings, approaches and organization of learning in project work.
The PBL model viewing the process as 3 separate project stages including; problem analysis, problem solving and project report, with focus on problem solving through analysis. Design Based Learning viewing the process as series of integrated design spaces including; alignment, research, mission, vision, concept, product and process report, with focus on innovative ideation though integration.
There is a need of renewing the PBL to update the educations to meet today's competitive global society. In order to create an informed basis for discussing and updating the historic approach to project work at Aalborg University, this paper will try to unfold and compare PBL and DBL and the competences they create through team based project work
The paper will exemplify how projects work is organized, supervised, staged and reported. It will investigate the practical organization of the teamwork and process as well as the dominating mindsets and methods used during the process. Comparing the two models concerning the learning aims the competence they create.

*Keywords: Problem Based Learning, Design Based Learning, Design Thinking, Project models, Teamwork*

## 1 INTRODUCTION

All educations at Aalborg University has since 1974 been rooted in Project and Problem Based Learning (PBL) model. In 1999 a new cross disciplinary design-engineering education in Industrial design was set up. This education program introduced Design Based Learning (DBL), which extended the approach to both project work and learning. The new education program still had to satisfy the overall academic standards at Aalborg University.
The first reactions to the new design thinking based approach were statements like "these people have no process", "it looks pretty messy", "it is not research based" and "how do you define design?"
A big but welcoming challenge when you need to collaborate with colleges from different teaching cultures on developing a new educational and research field. Anyway as a design thinker yourself you are aware of the importance of god communication and the strengths of visualizations as media to facilitate it.
A visual model named Design Navigator gradually evolved through two streams of thought: design and learning. The model became a tool supporting a common understanding of design and was used many collaboration contexts. Lately there has been a more formal discussion concerning the updating of the PBL model at Aalborg University. For this purpose attempts to clarify the differences and similarities between PBL and DBL has been made.

## 2 PROJECT BASED LEARNING

Drawing upon the article by Helle et al (1) on Project Based Learning the following definitions are selected for this section as useful to build a basis for the topic of this paper.

Project Based Learning is widely used in higher education. The term project-based learning subsumes different activities with varying purposes (1).
Helle et al (1) states that according to Adderly et al, (1975) project method is defined as: 1) Involve the solution of a problem; often, though not necessarily, set by the student himself; 2) Involve initiative by the student or group of students, and necessitate a variety of educational activities; 3) Commonly result is an end product (e.g., thesis, report, design plans, computer program and model); 4) Work often goes on for a considerable length of time; 5) Teaching staff are involved in an advisory, rather than authoritarian role at any or all of the stages – initiation, conduct and conclusion.

### 2.1 Project based learning versus problem based learning

Helle et al (1) refer to Blumenfeld (1991) saying that "the essence of project-based learning is that a question or problem serves to organize and drive activities and these activities culminate in a final product that addresses the driving question" Stating that he most distinctive feature of project-based learning is problem orientation. This was according to Dewey (1933) at the core of ''scientific'' or ''reflective'' thinking, which in his view, should have constituted the goal of the education. Concerning the relationship between project-based learning and problem-based learning (incidentally both abbreviated ''pbl''); the starting point in both approaches is a problem but in problem based learning, students' activity is directed to ''studying'', whereas in project-based learning, students' activity is directed to constructing the product. (1)

### 2.2 Project based learning versus experiential based learning

Experiential learning as learning from experience bears a resemblance to the original model of project-based learning Kilpatrick (1921). He distinguished four types of projects. The first type represented those experiences in which the dominating purpose was to do, to make, or to effect: to embody an idea in material form (compose or design). The second type involved purposeful enjoyment or appropriation of an experience. The third type of project the dominating purpose was to solve a problem. The fourth type, the learning project, included experiences in which the purpose was to acquire some item or degree of knowledge or skill. (1)

### 2.3 Collaborative or cooperative learning

The distinction between these two terms is often defined on the basis of the extent of shared activity: characteristic of cooperation is the effective division of labour while collaboration requires participants to solve a problem or perform a task together Teasley and Roschelle (1993). Project work is usually divided among participants but, at the same time, the aim is to construct a shared outcome. Thus, project-based learning involves both cooperative and collaborative elements.

## 3 DESIGN BASED LEARNING

Design is a complex interactive and dynamic process of transformation and so is learning; design in order to conducts ideas that create values through transformation of information and knowledge; learning in order to create knowledge, skills and competences.

### 3.1 Design Thinking

According to Brown (3) design thinking "begins with the skills designers have learned over many decades; put design tools into the hands of people who have never thought of themselves as designers and apply them to a vastly greater range of problems relies on our ability to be intuitive, to reorganize patterns, to construct ideas that have emotional meanings as well as functionality, to express ourselves in media others that words and symbols and taps into capacities we all have but that are overlooked by more conventional problem solving practices"

### 3.2 Design as process

Drawing upon the article by Beckman and Barry (2) on innovation as a learning process, the following information is selected as useful in building a reference for the topic of this paper.
"The history of academic understanding of the design process displays both a need to make design thinking explicit and a need to embrace the many disciplines engaged in design. Designers determine that their trial-and-error methods of design, in which they identified flaws and fixed them in a process of successive approximation to a final solution, need more predictive and evaluative methods for

determine the suitability of a design". "Looking at design as a social process design has further shifted from a clear-cut problem-solving process to a problem-formulating process in which getting to a collectively acceptable starting point become the core of the effort" (2)

### 3.3 Design as a process of knowledge creation

According to Owen (1997) the design process has "recognizable phases, and these, while not always in the same order, nearly always begin with analytic phases of search and understanding, and end with synthetic phases of experimentation and invention" and views design as a "process of knowledge development" suggesting that "the design process has both analytic and synthetic elements, and that it operates in both the theoretical and practical realms". In the analytic phases of design, one focuses on finding and discovery, while in the synthetic phases of design, one focuses on invention and making (2).

### 3.4 Learning as a process of reconstruction of experience

Dewey (1938/97), propose that learning is an ongoing "reconstruction of experience that reconciles new experiences with old ones in a continuous learning process". According to Kolb` (1984) Experiential Learning Theory learning is defined as "the process whereby knowledge is created through the transformation of experience" He defined the learning process as applying the four steps of experiencing, reflecting, thinking, and acting in a highly iterative fashion. His experiential learning theory model juxtaposes two approaches to grasping experience including; concrete experience and abstract conceptualization and two approaches to transforming experience including; reflective observation and active experimentation (2).

### 3.5 Learning styles and experiential learning

Beckman and Barry (2) suggest that the experiential learning theory model with its dualistic approaches to respectively experience grasping and experience transformation placed in a matrix "define four learning styles and individual learning preferences; diverging (idea generation activities); converging (technical tasks and tasks dealing with social interpersonal issues); assimilating (take in a lot of information and logically ordering it); accommodating (hands-on experience and action)". Barry further state that learning style is not a fixed trait in an individual, but according to Kolb "arises from consistent patterns of transaction between the individual and his or her environment".

## 4 PROBLEM BASED PROJECT IN AAU CONTEXT

The PBL introduced at Aalborg University in 1974 as a studying model which include; Project and Problem Based Learning, project organized education, inter disciplinary studies and group work (mono disciplinary). The PBL process model holds the 3 stages; Problem Analysis, Problem Solving and Project Report. The model is a linear stage-gate model embedding discursive thinking.

### 4.1 PBL and project work

The duration of a project work is 4 month. The project groups between 3-7 students. Lectures on related topics and supervision are provided throughout the project period. Problem area is given but stated in a problem formulation by the students groups based on Problem Analysis. Problem Solving includes literature studies, group studies, field work and experiments. Project output is a Project Report including results of analysis and problem solving as well as the applied theories, methods and references.

Instructions concerning project work delivery include; problem formulation, synopsis, report structure and citations are provided when students enters an education

### 4.2 Project types and group formation

Project types include; Problem projects, Discipline projects and Task projects. Problem and discipline projects can both be analysis, construction and design projects whereas Task projects can only be analysis or construction projects. Project often include cooperation with companies or public organizations. Master students are responsible of finding and framing the problem. Interdisciplinary studies include; integration of theory and practice, learn to learn and scientific methodological skills. Analysis represents the main part of the project. Students tend to focus on the project report as the purpose of the project work. They are responsible for creating the project groups without any facilitation.

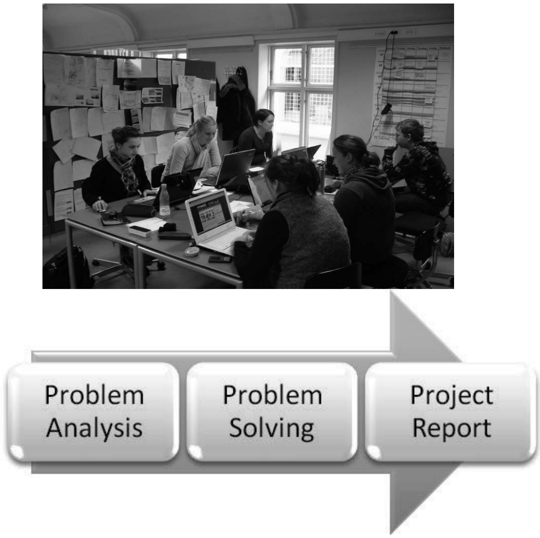


*Figure1. Staging PBL based project work*

### 4.3 Project supervision and staging

Supervision is linked to the Problem Solving phase and includes; lectures and tutorials. Each group has two supervisors of which one is a main supervisor from the specific education and the other either from the PBL institute or a relevant related education. The supervision format includes meetings and mail correspondence.
PBL project work is staged in group rooms with a meeting lay out. Students are responsible for both project and team management, but are not provided with any methods or tools for the purposes.

## 5 DESIGN BASED PROJECT IN AAU CONTEXT

The DBL introduced at Aalborg University in 1999 is extending the studying model to design thinking model which include; Project Based Learning, project and workshop organized education, inter-disciplinary and process studies and group work (mono and multi disciplinary).
The DBL process model holds the 6 platforms; Alignment, Research, Mission, Vision and Product. This interactive model is embedding both intuitive and discursive thinking.

### 5.1 DBL and project work

A project period can be 6 or 12 weeks. The project groups between 3-5 students. Lectures on related topics are an integral part of separate workshops including a minor 3 week individual project. Project supervision includes facilitation of teamwork, project organization and management. The clear-cut problem solving process is replaced by a problem and potential finding process as a core element of designing innovative solutions. Project output is a Product Report and a Process Report; the first holding a description of the design proposal and the second holding a description and reflection on the design process.
Instructions concerning project delivery content and format; product report, process report, slide presentation, physical models, boards and working papers are specified for each project in a study guide.

### 5.2 Project type and group formation

Project types include; Minor Discipline and Experimental projects, Major Problem and Potential based design project. Projects work in general focus on and “designing to learn” and “learning to design”; the ability to navigate the process and master design methods and tools. Analysis and synthesis are seen as a mutual interactive process. Major projects include cooperation with companies or public organizations. Interdisciplinary studies include; integration of theory & practice and scientific & artistic skills. Synthesis represents the main part of the project. The students use the process report to scale the progression in their design competences. The groups are facilitated on team creation and collaboration.

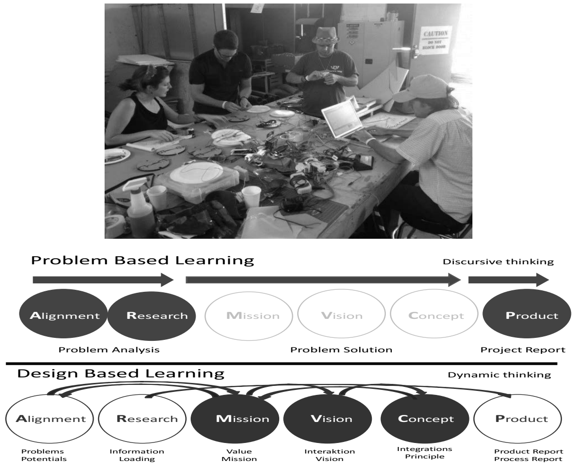


*Figure 2. Staging Design based project work in the context of PBL*

### 5.3 Project supervision and staging

Each group has a design and an engineer supervisor. Supervision includes all process platforms. To facilitate design thinking a Design Navigator (4) is used. It provides a framework including a set of parameters for what you are working with– the product and a set of levels for how you are working – the process and integrates the two systems. The product dimensions state 8 basic parameters. The process dimensions define 4 levels each framing a certain way of working concerning your thinking mode and communication form.


*Figure 3. Design Navigator for co-creation process facilitation*

The firm and simple structure allow the group to move freely among the parameters and levels while at the same time securing attention and supporting communication. The tool works as design arena and together with intensive use of the floor and walls it create a flexible and facilitating project space for collaborative design thinking, actions and reflection. Supervision mainly takes place within the project space.

## 6 DISCUSION ON PBL VERSUS DBL

Here I will try to examine differences and similarities in PBL and DBL as it comes through in team based project work in specific concerning; 1) Project model and process approach; 2) Project driver, support and staging; 3) Learning and working modes 4) Competence creation.

| Project model - process approach | Process driver, -support -staging | Learning and working modes | Competence creation |
|---|---|---|---|
| **Problem Based Learning-PBL**<br>Stage-gate model<br>Analytic approach<br>Problem solving | Problems<br>Analysis and construction<br>Tutorials, lectures and literature<br>Cooperation<br>Meeting space | Assimilating (logic info ordering)<br>Converging (technical tasks) | Scientific competence<br>Discursive thinking<br>Subject management<br>Project report |
| **Design Based Learning-DBL**<br>Systemic model<br>Interactive approach<br>Potential exploration | Potentials and problem<br>Synthesis and innovation<br>Facilitation and tool provision<br>Collaboration<br>Workshop space | Diverging (idea generation)<br>Accommodating(hands on action)<br>Converging (technical tasks)<br>Assimilating (logic info ordering) | Innovation competence<br>Design thinking<br>Process management<br>Product report & Process report |

*Figure 4. Comparing PBL and DBL*

### 6.1 Project model and process approach

Project models traditionally represent a procedure of how to progress and thereby create a specific way of working initiated by a problem or purpose. Furthermore they also affect the mindset; embedding discursive thinking. Stage-gate models like the PBL model are well-entrenched in contexts dealing with traditional problem solving. However struggling with increasingly broad and complex challenges this model is inadequate and causes a need of system models and to seek understanding of fundamental principles of interactions between problems and potentials and between analytic, synthetic and reflective thinking.

### 6.2 Process driver, support and staging

Projects serve to organize and drive constructions activities. Problems serve to organize and drive studying activities. Lectures, literature and tutorial might be suited for academic projects dealing with the past and present but is not adequately when dealing with the future like you do in design and innovation.

Design is a highly dynamic and complex process which involves navigating both what you are working with and how you are working. When project group enters discussion, negotiation and decision making on design matter, they need interactive facilitation to support their thinking, actions in the process of co-creation.

Collaborative project work do not work out in the context of a conventional auditorium or meeting room as it implies interactions of thinking and emotions involving both mind and body. Communication in design should be staged in a way to actively support expression, sharing and interaction. A flexible project space, which allows a diversity of action and interaction, will act as a facilitating partner in the project work.

### 6.3 Learning and working modes

Designing and learning are both complex interactive and dynamic transformation process`; designing in order to conducts ideas that create values through transformation of information and learning in order to create knowledge, skills and competences through experience.

The PBL process presents a clear differentiation between analysis (assimilating) and synthesis (converging) as separated project stages, which leads to the misunderstanding that solutions with occur on the basis of thoroughly amount and quality of analysis, which is obvious not the case. In the DBL process the participant moves between concrete and abstract modes. It alternately uses analysis and synthesis to generate new designs. In moving among those extremes, in essence requires participants to engage in concrete experience and abstract conceptualization, reflective observation and active experimentation thus exercising all four learning styles; diverging, assimilating, converging and accommodating.

### 6.4 Competence creation

PBL primarily create competences in scientific theories, methods and reporting and knowledge management within a specialized field as well as promoting a culture of discursive thinking and an analytical oriented working mode in relating practice to specific theories. DBL primarily create competences in design and innovation theories, methods and tools and knowledge management within an integrated field of subjects as well as a culture of systemic thinking and a synthetic oriented working mode relating new concepts to future practice; to take holistic approach to design and work in the cross field of science - innovation and conduct ideation and product development carried out by cross disciplinary teams.

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Chapter 6

# DESIGN EDUCATION AND DESIGN CULTURES

# CURIOUS DIRECTIONS FOR PRODUCT DESIGNERS: HOW TECHNOLOGY IS AFFECTING MEDICAL DESIGN PRACTICE

**Jennifer LOY**
Griffith University

**ABSTRACT**
Medical product design practice has changed over the last five years as advances in technology, both digital and practical, have opened up new opportunities to address patient needs in innovative ways. This paper identifies examples of new practice, considers how the role of the medical product designer has responded to the web of advanced technologies impacting communication and production, and suggests directions for product design education to build collaboration and project work to provide students with the transdisciplinary understanding, skills and knowledge they need to meet these specialised industry demands.

*Keywords: 3D printing, software, medical, health*

## 1 INTRODUCTION

The product design profession has developed incrementally since the first industrial revolution, with advances in technology building on previous practice, adding successive chapters on design for production. Ideas and values have changed, influencing design directions, with sustainability in particular impacting design through consideration of product lifecycle in design, however, the underlying body of knowledge that informs the discipline has expanded cumulatively, at least until recently. In the last five years that has begun to change as advances in digital media have broadened the scope of the Product Design discipline, and continue to do so. Yet to meet these emerging opportunities, Product Design educators are recognising that the accumulated knowledge and practice, in particular in relation to production, needs to be revisited with a fresh perspective that responds to being a designer now, in a digital world, as opposed to previously when the impact of digital media was essentially limited to computer numerically controlled manufacturing.

Design for health projects provide a particularly interesting example of how advances in digital technologies are opening up new directions for product designers and creating new collaborations, in this case between clinicians and designers. Medical researchers and practitioners have strayed into territory that could be deemed product design as the 3D digital technologies recently developed have been championed by clinicians in direct response to their needs in treating their patients, whilst product designers are equally finding themselves involved in medical based product design that challenges conventional practice.

## 2 DIGITAL TECHNOLOGIES

The main digital technologies that are impacting medical product design are in softwares that supports the manipulation of 2D to 3D scan data; digital communications tools such as Apps; and 3D printing. Apps, for example, are providing designers with new opportunities for communication that are being used in service design for health that are innovating practice. These are predominantly focussed on supporting health management and nursing care, with communication and health data tracking particularly prevalent. Whereas there has previously been a division of labour between the design of the product and the digital component, students are now working across boundaries as technology makes digital drivers more accessible [1].

The development of 3D printing for medical applications has influenced the development of the 2D to 3D scan data manipulation software over the last twenty years [2]. 3D printing itself is a term that refers to a range of production processes that build objects from the ground up, in layers, without the need for tooling such as moulds [3]. Technically known as additive manufacturing, these technologies are driven by 3D computer models, and can use single or multiple materials to build forms. The most basic form of additive manufacturing is fused deposition modelling which is essentially a filament of material, most commonly a thermoplastic polymer, extruded through a heated print head mounted onto a stepper motor with a heated platform for adherence, that lowers incrementally to allow for the build. These machines can extrude multiple materials for increased complexity, particularly through the use of soluble materials that works with the part material to create scaffolding to support undercuts and complex internal geometries in the model. Fused deposition modelling is used in medical projects predominantly to build planning models. These can also be constructed from cellulose based materials in a powder form that is fused using a binder extruded from a series of print heads, much like a 2D printer. These models are less permanent than those created by the fused deposition modelling machines, which tend to print in acrylonitrile butadiene styrene (ABS), but for medical planning applications this is not usually an issue. There are engineering grade printers that work at a micron level to print UV cured resin supported by a wax scaffold that are used in medical product design applications and in this case the part / support material can be reversed so that the wax can be printed for casting applications, used in conventional medical product design.

Medical applications predominantly use metals in the print, in particular titanium in a mesh form designed to allow human cells to grow into the structure. The titanium is powdered and laser fused in a process called direct laser melting, that is similar to selective laser sintering except that it is a cold process, whereas polymer based selective laser sintering takes place in a heated chamber. This difference has significant implications in relation to the importance of software that enables the user to work directly within an actual STL file, manipulating the design to reduce post processing. This is vital for metal processing, as the cold chamber means that the remaining powder does not act as a support structure (whereas it does with heated polymer powdered 3D printing) meaning a scaffold will be printed with the part, not dissimilar to that in fused deposition modelling. As post processing of metal is currently labour intensive, it needs to be reduced to the minimum.

All additive manufacturing technologies create objects without the need for a preformed mould. This lack of upfront investment means that customised products can be created. This single factor has the most impact on innovations in medical product design and implications for designers working in the field as customisation for individual patients is the ideal for any medical design application. In addition, fundamentally more complex objects (particularly in regards to internal geometries), tailored to an individuals needs, can be developed than previously, as even multiple-part moulds must be designed taking into account the path of the tool tracking out of the object. For medical project design work, both internal and external to the body and in respect to customised instruments for example, the complexity and individualisation that 3D printing now allows, and the sophistication of the suite of softwares that support the manipulation of 2D to 3D data blur the boundaries between disciplines.

## 3 MEDICAL PRODUCT DESIGN

For direct medical applications and more broad healthcare product designs, from implants to customised hearing aides, working with software that enables the translation of 2D scan data into 3D forms is the starting point for most objects to then be physically produced using 3D printing. Because of this, it has been medical practitioners who have been the early adopters of the software and subsequently driven the 3D printing of medical products, not Product Designers. Yet this practice means that the proven capabilities of Product Designers in user design, creative problem solving and optimising product design for production are not yet utilised.

One of the most significant areas of changing medical practice that is providing new directions for medical product design, is in surgical planning. The development of surgical guides for complex situations is a cross over between medical and product design. Currently it is the realm of interested medical researchers, rather than product designers, but collaboration with product designers would potentially provide innovative approaches to the design and construction of the guides that could move the development of the application forward. Dr Raphael Olszewski is one of the leaders working with 3D printing and scanning to develop a method of surgical planning for complex procedures. He scans the patient's bone, constructs a 3D computer based model of the bone from the scans and 3D prints out multiple copies of the bone on which he can practice his surgery. Once he has planned the best surgical procedure, he develops surgical guides that are also 3D printed, that can be inserted onto the bone to ensure the cut is accurate to the planning [4].

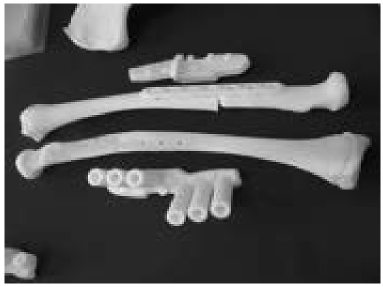

*Figure 1. Surgical guides are developed using 3D printed practice bones and 3D printed (photo c J.Loy)*

Developing surgical guides is becoming increasingly complex, as their potential is explored for multiple applications. Informed collaborations between Product Designers and clinicians to consider the operation as a whole, rather than the guides at the their most basic functional level, could potentially result in evolved surgical tooling that supports the process of the operation as well as precision placing of cuts and implants.

### 3.1 Mechanical support structures

Human exoskeletons have been used for adult patients affected by conditions such as arthrogryposis multiplex congenital that cause stiff joints and under developed muscles, to help the patient to move more easily. However, these exoskeletons are complex mechatronics and there have been restrictions in what it has been possible to make for younger patients. Researchers Rahman and Sample work on mechanisms to support movement in patients with neuromuscular weakness due to muscular dystrophy or spinal muscular atrophy [5]. They developed an exoskeleton called WREX that was fitted to a wheelchair and suitable for children as young as eight, but had to push the boundaries to develop an exoskeleton to fit a two year old, Emma Lavelle, who was not restricted to a wheelchair. 3D printing allowed the researchers to scale down an exoskeleton in weight and size to fit [6]. This innovation suggests new directions for mechatronic design for engineers and product designers to work in, to problem solve in ways that were not previously possibly to functionally address.

*Figure 2. 3D printing is providing new opportunities for medical product design of exoskeletons (photo c Stratasys)*

Product designers can contribute to this field of work by bringing the user interaction, experience mapping approach embedded in the discipline and also the creative thinking based on situation design approach to problem solving in this area that clinical researchers are not specifically educated in. An example from a medical product design that illustrates this point is in the development of the Jaipur Knee [7]. The Stanford-Jaipur low cost prosthetic knee was designed by the Stanford University, USA, working with the BMVSS team and hailed by *Time* magazine (issue of November 23, 2009) as one of the 50 Best Inventions of the World in the year 2009, yet it was initially engineering driven rather than situational design driven. The initial design for a low cost prosthetic knee focussed on mechanical function, and less on the user experience or cultural referencing. The knee initially clicked during use, forcing users to adapt the mechanism, and was not suitable to be used in the squatting and cross-legged sitting positions favoured by the Indian population it was designed for. These are issues that a product design approach to initial user research informing design could have prevented.

## 4 MEDICAL IMPLANTS

These applications build on the skills required for the surgical guides to create medical implants using 2D CT scans that are constructed into a 3D model. The morphology of the organic material is mapped in the process, and gaps in the data – which are currently inevitable in the translation of the 2D scan data into 3D data – bridged in the modelling. An example of this is the development of a replacement hip joint. This is not a straightforward exercise, as the joints can be degenerated, for example due to tumours that have been removed that have affected the topology of the joint.

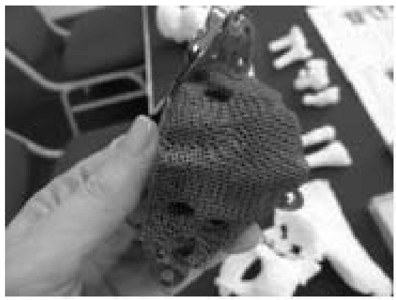

*Figure 3. Titanium hip joints, such as this one, can now be 3D printed in complex geometries that are customised to match the patient's remaining bone (photo c J.Loy)*

The surgeon must make decisions in relation to the development of a replacement joint that can potentially move across into product design with the innovations possible with 3D printing, that allow for multiple part assemblies that can conceivable change not only the form of replacement parts but also more radically the development of innovative replacement joints. This is particularly interesting for the replacement of complex joints such as ankle joints. If the ankle has been severely broken patients will develop a potentially debilitating arthritis in that joint approximately five years after the initial break. Currently the treatment for this is to fuse the bones in the ankle, which results in a lack of mobility in the joint. This restricts the patient's movement impacting involvement in certain types of sports, such as surfing. This is an area of research that Product Designers could significantly contribute to as current research suggests that dynamic medical modelling and 3D printing opens up the possibility of redesigning ankle joints, as illustrated by the work of Panagiotopoulou on comparative locomotor mechanics [8]. Joint design based on 3D printing could potentially move beyond copying the action of an original joint, but rethink it, particularly in relation to a specific task. Product designers in collaboration with medical researchers could significantly contribute to this area of study.

## 5 NEW DIRECTIONS FOR PRODUCT DESIGNERS

Medical practitioners have been the early adopters of the 3D printing for medical applications because of the starting point of using CT scans for the construction of 3D forms for implants and, for example, skull plates so if Product Designers are to maximise the potential this starting point provides, design education will need to provide students with the digital skills to work with CT scan data and STL manipulation (these are the files produced specifically for 3D printing that it is possible to optomise and adapt for production with dedicated software) that medical practitioners are developing as well as an in depth understanding of the hardware for 3D printing. Product designers can then bring their innovative practice, based on user centred, situational design research skills, to collaborative practice.
There are examples of emerging practice by product designers that are responding to the opportunities that digital media innovation is providing for medical projects. For example, emerging practice shows that product designers are working with clinicians exploiting the application of 3D printing technology in the customisation of product for design and health applications. An example of this practice is the work of Bespoke Innovations™, Inc. This company was founded as a collaboration between an Industrial Designer and an Orthopaedic Surgeon. Their stated mission is to 'bring more humanity to

people who have congenital or traumatic limb loss' [9]. This product design company developed individual prosthetics for their clients to meet their emotional needs as well as their individual functional needs; for example, the design of a leg prosthetic for a footballer, or a cyclist differs from the leg most suitable for a motorcycle enthusiast. This level of customisation allows for innovative thinking, such as designs that go beyond replacement into enhancement.

*Figure 4. Bespoke Innovations product designers use 3D printing for customised prosthetics (photo c Bespoke Innovations)*

For product design educators, preparing students for work on emerging medical design applications, based on innovations in digital media, involves not only helping them to develop new practical skills to an advanced technical level but also develop specific relationship skills aimed at promoting effective collaborations between designers and clinicians. Promoting a shared language, culture of design development and understanding of practice will support genuine collaboration, over a clinician / technician relationship, that is more likely to lead to innovation. It does require commitment, but there are opportunities emerging that suggest it will be a worthwhile development for product designers for the future, taking their work in unexpected directions. Fripp Design and Research is an example of a product design consultancy exploring these new, collaborative directions. Fripp Design and Research is a Sheffield based consultancy who work with the University of Sheffield and the Wellcome Trust to develop improved soft tissue prosthetics from a user point of view [10].

*Figure 5. Fripp Design and Research collaborate on the design of 3D printed soft tissue prosthetics (photo c Fripp Design and Research)*

## 6 CONCLUSION

3D printing is changing the role of the medical industrial designer by creating new opportunities for supporting health and wellbeing in a curious range of applications. The involvement of product designers in design for health tends to be service design based projects, such as way finding, and the design of practical equipment dedicated to specific tasks within the clinical environment. The practice of designers in this area has developed within the discipline generally in much the same way as commercial product design, with designers working with clinicians and users to create product responses to problems working within the conventional parameters of production and marketing. Product designers have still needed to meet a market based on mass production or at the very least batch production conventions in order to be viable. It is a particularly demanding area of design due to the regulations the designer must be aware of and work with. Design practice has been refined in these areas with specialist consultancies emerging, but their work has been constrained by the commercial restrictions of the industry. Because of this, product design has to compromise in its service to this industry, resulting in products that meet the needs of a broad percentile of the users in situations where bespoke, innovative products would be the ideal.

The last five years have seen dramatic changes in production potential for specialised products, with 3D printing (technically called additive manufacturing) emerging from a prototyping technology into a technology for direct manufacture. This is transforming the relationship of product designers and clinicians, and suggests new directions for product design education to meet the opportunities and requirements of this new relationship. Technological developments are bringing the digital and the physical together in new ways that are challenging the nature and scope of the traditional project work in this area for medical based product design, and so will impact future directions for curriculum planning. To understand the opportunities and anticipate the needs of graduates to maximise those opportunities in the future, examples of innovative practice are described, though currently these are often developed by clinicians learning 3D computer skills and aspects of product development, rather than product designers themselves (although this is not always the case), suggesting the potential for further development with the direct involvement of trained product design innovators in the future.

For educators in Product Design curriculum development, the implication of these developments is a review of traditional design practice teaching. If Product Design education were to be proposed and developed as a new area now, rather than as an evolution of an existing discipline, then based on the emerging opportunities illustrated by the examples in medical design, digital media would take a more significant role in the curriculum and the designer would be positioned as a collaborator providing interactive morphology rather than fixed, resolved outcomes. As additive manufacturing eliminates the need for investment in tooling, the relationship of the designer and client shifts into a new paradigm. To maintain its relevance, Product Design in higher education will need to shift with it, or risk being subverted by more flexible market providers.

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# INCREASING POLICE TRUSTWORTHINESS THROUGH A USER-ORIENTED DESIGN APPROACH

**Bente MOEN, Jarle FOSSE and Arild BERG**
Oslo and Akershus University of Applied Sciences

**ABSTRACT**
This study addresses the research question of how product design can enhance and strengthen the general public's positive perceptions of the police in Norway. Product design expertise can be used to gain valuable insight into human-technology relationships, the general public and the possibilities within the field of crime prevention. By considering product design methods and tools, this study aims to call attention to an overlooked development possibility for interaction between the public and the police. The public expects the police to protect it, to prevent and solve crimes and to arrest criminals, in order to preserve safety and trust. Research on police practice has shown that the police are seen as service providers, and that the public is regarded as a static user and observer of police services. The product design approach that is applied in this study regards the public, to a greater extent, as a provider of the means of preventing crime. This paper uses studies of police surveys, reports and research on police practice in its methodology. For this study, interviews and observations of both individuals from the public and the police were carried out. This paper presents new insights from a product design perspective, which can contribute to filling the knowledge gap in interactions between police and public relations. The resulting knowledge can be used in practice to strengthen bonds between the police and the public, and to enable better prevention of crime.

*Keywords: Product design, technology, service, police, trust, knowledge, public, safety*

## 1 INTRODUCTION: POLICE-PUBLIC RELATIONS AND THE PUBLIC TRUST

In past decades, the government and the police have focused greatly on means of creating and trust through strategy and proper police work [1]. However, trust involves trustworthiness [2]. Previous research shows that much work has been carried out on this topic by the police and the government. But little on the publics views. A recent program has aimed to add value and unify the police force, in order to ensure that the public experiences comprehensive and effective policing [3]. It should be easy for the public to engage in dialogue with the police, even through digital channels. All police officers should have access to user-friendly and mobile tools that allow them to solve and finish more jobs in the public space. The use of new technologies will enable police officers to work more intelligently, share knowledge more easily and effectively and respond faster, with better analysis as a basis for fighting crimes.
This topic became tragically relevant in a new way after the horrifying terrorist act in Norway, when on 22 July 2011, a terrorist slaughtered innocent young people and bombed a government building, killing 77 people and wounding 66. This madman's actions have raised many questions in Norway. Among them is the ongoing public and governmental debate on whether Norwegians want a visibly armed police in Norway, and whether such a police force would increase trust in the police.

### 1.1 What trust is and how it is earned

Vilhelm Aubert has argued that trust is a characteristic of interpersonal relationships, and emphasizes that predictability among participants is a crucial aspect of the relationship of trust [4]. Predictability is a factor that the police have some difficulty defining in relation to the authority and trust that the public grants them. The term 'the big collaborative project' has been used by Liv Finstad to address the police's greatest job within Norwegian society [5]. Finstad states that public-oriented activities are the most reliable source of trust, support and confidence for the police. She also points out that trusting

relationships are not only necessary for the police to be able to perform tasks, but to carry out crime prevention and investigation services. This strongly supports Aubert's position. One threat to trustworthiness is that a single police officer can come to embody more than just an individual, and will represent both what lies within and behind the uniform. According to Larsson it is shown that those who have the most contact with the police have the least confidence. It seems reasonable to assume that this also applies to the reputation of the police, although this cannot be treated as empirical because of the basis of the profile surveys'. [6]
The researcher Marianne Sætre believes that criminology development has focused on creating direct and explicit hypotheses about crime as a construction, and has avoided addressing criminal actors as active participants [7]. Further to this, Tine Holm argues that the consequences of what Sætre calls a frozen standpoint theory are that scientists must choose between theories recognised by the research community, while so-called 'free research' is largely restricted and narrow in focus.

### 1.2 Industrial design possibilities: Interaction between the police and public

The concept of product design involves a duality in the tensions between different target groups and professional standpoints. Design takes place within a whole range of development areas and fields of focus, such as subject and context, form and function, the ancient and modern, natural needs and social needs and production costs and expectations of the target group and finances. Successful design is not about compromise but about doing justice to the different poles of these fields of focus [8]. In his studies on innovation, industrial designer Robert Curedale states that the goal of design thinking is to understand, observe and identify what users want from a product, service or experience [9]. Design thinking methods such as customer journey maps help designers cross disciplinary boundaries and design less tangible or physical services and experiences that change over time. As design takes place within a wide-ranging area of development, with the designer as both a listener and facilitator, design may reveal many new possibilities, as product designers always focus on both users and human values [9].

### 1.3 Preventing crime with the help of the public

Studies of any profession risk becoming too self-centred and providing solutions that are monotonous with few new insights [10]. Previous research has focused on work carried out by the police and the government, while little research has been carried out to explore insights from the public's side. This knowledge gap makes room for design approaches that focus on public user experiences as a means of expanding existing horizons and gaining valuable new insights. This is the background for our central research question: how can product design increase trust within the police-public relationship?

## 2 METHODS: LITERATURE REVIEW AND INTERVIEWS

### 2.1 Qualitative methods for understanding daily experience

In this study, qualitative methods have been used with the aim of exploring and gaining new insights into the issues in question [11]. Curedale argues that qualitative research seeks to understand people in the context of their daily experiences, in terms of questions such as 'why' and 'how', and to develop an initial understanding of an issue [9]. In this study, semi-structured open-ended interviews were used to gain data [12]. The ability to delve deeper into concerns through interviews is a strong argument in favour of their use. By asking questions that explore a wide range of concerns about a problem and giving interviewees the freedom to provide detailed responses, researchers can use interviews to gather data that would otherwise be hard to capture [11]. Through concept mapping [13] and pattern matching [14], this study aimed to visualize relevant issues as a tool for design practice in the public-police relationship.

## 3 FINDINGS FROM THE PUBLIC AND THE POLICE

### 3.1 Initial focus group interview:

In the initial stages of the study, we gained a basic understanding of information related to the police and armaments with regard to the public, and started with the assumption that the general public would lose faith and trust in a visibly armed police force. This sparked our desire to test the assumption in relation to the views of the general public. We then arranged an initial focus group interview. The focus group involved interviews with three students from a master's degree program in product design, two of whom were Norwegian and one of whom was Mexican. The interviews were based on an open-ended approach. Simple wording was used to ask students to elaborate on topics, with regard to their views and experiences. The interviews were conducted with one facilitator asking questions and helping the flow of the conversation, and two moderators recording answers and interesting notions. One issue with the use of a small focus group is that it did not cover a sufficient number of individuals to properly represent the Norwegian general public and validate the findings. In some cases, the answers may have been contaminated by the facilitator, who aimed to clarify certain issues.

#### *3.1.1 A visibly armed police force would signify an unsafe society*

The interviews conducted with the focus group provided insight into the mindset of a small group of people that somewhat represented the general public. The participants' answers indicated their generally high level of trust in the police, while the most valuable insight came in the form of the group's disapproval of the assumption that 'the general public would lose faith and trust in a visibly armed police force'. The interview subjects commented that they would not necessarily lose faith in the police, but that 'a visibly armed police would signify an unsafe society'.

### 3.2 Individual interviews: Associations with visually armed police

In order to collect more reliable and valid data within the area of research, a second set of interviews was devised to prevent contamination from the facilitator. The subjects were asked to provide feedback on a set of photos, in order to present open but directed questions and collect data on associations and emotions evoked by the images. A larger group was examined, in order to better represent the general public. The participants were an elderly man of roughly 60 years of age, a woman of roughly 50 years of age, three women of roughly 20 to 23 years of age and two men of 25 and 33 years of age, last one was an ex-soldier.

None of the participants had issues with the police carrying weapons, and all stated that they had confidence that the police would handle weapons appropriately. However, they also argued that the visibility of weapons in public spaces would signify an unsafe society.

These interviews explored the reliability and validity of the insights gained through the initial focus group interviews [11]. Police researchers have pointed out that in order to keep Norwegian society safe and prevent crime, police are dependent on the public's trust and cooperation with the police as authority figures [15]. Initial research on the public's views on guns within the public arena shows that the police desire for armament for defence could lead the public to believe that Norwegian society is unsafe. This perspective could lead to a public loss of faith and trust in the government and the police, which would greatly harm Norwegian society as a whole. This conclusion may be based on preliminary research, but highlights the value of looking deeper into the public's needs, emotional perspectives and semiotic views in assessing whether to visibly arm the police, as well as in considering issues that affect the public and the police.

### 3.3 Qualitative interview with an experienced police officer

A qualitative interview was carried out with a police officer who has 25 years of experience in different fields, including ten years of fieldwork and experience in various management positions in different districts in Norway. He currently works as an investigator within the financial crime department's public correctional agency. He has been involved in the former renewal programs, as well as the NTL (Norsk Tjenestemannslag) a union for workers in the state sector. Because of his broad experience, he is participating in a group determining the new police strategy for added value. The Norwegian police are facing a paradigm shift with all reforms to be undertaken to build *One police - equipped to meet future challenges* (Ministry of Justice and Public Security, NOU 2013:9).

#### *3.3.1 Police culture and public trust*

The police officer explained that through experience, he realised that the biggest challenges for change within the police lay within their culture, as it fosters a lack of acceptance. He explained this by discussing the broad variations that exist in police cultures in cities and different districts. He argued that some police officers have a tough 'cowboy mentality', whilst others are more concerned about doing good and correct police work. He confirmed that most police officers are very keen to do their jobs correctly, and understand that their actions may be subject to verification and investigation, and thus should be valid. He pointed out that trust is a core issue, and he asked the following questions: 'Does police culture have a direct impact on the quality of policing that is offered to the public'? 'Can police approaches to goals, skills and technology, as affected by police culture, lead to mistakes and errors in approaches to legal rights'?

#### *3.3.2 Visibly armed police*

The police officer informed us that there are currently 40 employees and contractors working on the development of the project pilot for the new program for a unified police force (One Police). In considering this issue, product designers could focus on issues such as why the police want guns or other weaponry when it could mean sacrificing their unique trust relationship with the public. The underlying reason for this is that the police want easier access to weapons in order to be able to more quickly respond to emergencies. However, existing research shows that easier access to weapons increases their use, increases the number of gunshots fired and makes potentially deadly outcomes more likely. Our preliminary research also shows that the general public's trust and faith in the police and the government will likely decrease if police carry guns. The important question in this case is not whether the police should be allowed to be visibly armed, but what the police are willing to sacrifice in order to be able to do so. The police should have the right to equipment that enables them to defend themselves and the public, but this right should at no point challenge or potentially harm the realisation of the principles of society.

## 4 DISCUSSION: DESIGN THINKING IN POLICE PRACTICE

Existing research on police work indicates the necessity of involving other professional perspectives. Tine Holm writes that traditional police sociology has long been dominated by research on and around the police [7]. The police officer that we interviewed for this study stated that the police's largest risk and challenge is the existing police culture, and claimed that this was a reason for a lack of acceptance of renewal programs within the police. In past decades, the government and police have intensively focused on what creates trust and how to maintain it through strategic approaches and good police work [16]. Several studies on trust have also showed that this is a recurring theme. Existing police research involves a major focus on the great importance of public trust, and often states that the police do not only gain this trust through their work. Through concept mapping [13] and pattern matching [14] we developed, based on design theory, a visualization concerning practice both in policing and design. Combined with inductive and deductive approaches [17], the resulting 'police public oriented design' (PPOD) is a tool for visualising the fields where design practice can contribute in building a more trustworthy police and with the result of gaining public trust.

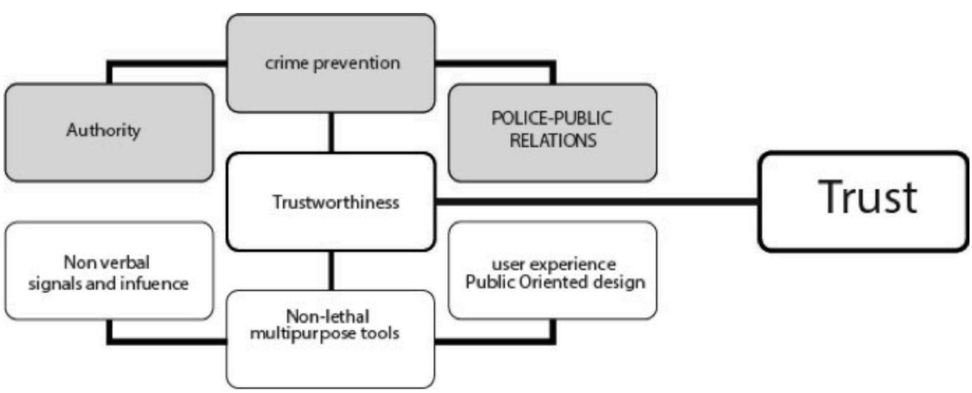


*Figure 1. PPOD visualization: Police public oriented design illustration presenting key concepts for design practice towards a more trustworthy police*

### 4.1 User experiences of trustworthiness: A design approach

In her work, the philosopher Onora O'Neill has focused on international justice and the roles of trust and accountability in public life [2]. She offers an enlightened approach to the debate, arguing that what matters is not trust but trustworthiness. She argues that individuals or groups have to earn trust by being trustworthy, and that we should thus think less about trust and more about attitude and adequate and simple evidence of trustworthiness. She concludes that trustworthiness is what we have to judge, and that trust is the response. This supports the idea that the best way to increase trust in the police may be by ensuring that the police is reliable and credible. What matters greatly in this regard are factors such as the response time and availability of the police. The police could probably benefit greatly by involving independent professionals such as product designers in related efforts, with an emphasis on design thinking, service- and product design; and the development of the future police force *One police - equipped to meet future challenges* (NOU 2013:9)

### 4.2 Systems of interaction

Design disciplines can explore new ways of expanding trustworthiness by looking more closely at systems of interaction, user experiences and usability and all related products. Exploring new technologies would probably show that major possibilities exist for innovation in the use of materials, uniforms and means of protection. Robert Curedale states that the goal of design thinking is to understand, observe and identify what customers (users) want in a product, service or experience, in terms of innovation [9]. He also explains that design thinking methods such as customer journey maps help designers cross disciplinary boundaries and design less tangible or physical services and experiences that change over time.

### 4.3 Acting to uphold our duties

Unless we take account of the positive aspects of trustworthiness as well as the negative aspects of untrustworthiness, it is not possible to assess whether we are facing a crisis of trust or only a culture of suspicion. From Onora O'Neill's perspective, it is not surprising that if we persist in viewing good news as no news at all, we end up viewing no news at all as good news. Perhaps the culture of accountability that we are relentlessly building for ourselves actually damages trust rather than supporting it. We would do better to begin by thinking about what ought to be done and who ought to do it, rather than about what we ought to attain. To restore trust, we not only need trustworthy persons and institutions, but also assessable reasons for trusting and mistrusting. According to O'Neill: 'Passive citizens, who wait for others to accord and respect their rights and mistakenly suppose that states alone can do so, are, I think, doomed to disappointment. Active citizens who meet their duties thereby secure one another's rights. The passive culture of human rights suggests that we can sit back and wait for others to deliver our entitlements. I suggest that if we really want human rights we have to act and to meet our duties to one another. The supposed "crisis of trust" may be more a matter of what we tell inquisitive pollsters than of any active refusal of trust, let alone of conclusive evidence of reduced trustworthiness. The supposed 'crisis of trust' is, I think, first and foremost a culture of suspicion'. [2]

### 4.4 Legitimacy and trustworthiness

Helene I. Gundhus points out what she sees as a weakness regarding the issue of trust in existing literature. She argues that it threatens trust in the police if citizens perceive the police to be trustworthy [16]. This is the opposite of what Onora O'Neill claims [2]. The literature that Gundhus refers to discusses why trust in the police is associated with legitimacy problems, regardless of whether the police exercise authority. While O'Neill points out that trust is earned through trustworthiness Gundhus claims that the issue of trustworthiness should be excluded from discussions on trust in the police, to avoid reducing the question of trust to a strategic game about image work rather than principles and norms of state legitimacy [16]. O'Neill argues that trust is difficult to measure, whilst trustworthiness is easier to measure, as it results in trust. The experienced police officer that we interviewed also argued that trust is a core issue.

## 5 CONCLUSION: DESIGN THINKING IN POLICE-PUBLIC RELATIONS

The conclusion of this study is that the PPOD illustration can be used as a visualization tool for possibilities in the interaction between the public, the police and design practice. Also that design thinking could potentially help the police develop new products. These products could, for example, enable police officers to carry defence equipment that is integrated into their uniforms. Based on the interviews in this study, it seems like such products could be designed in a way that takes into consideration both the needs of the public and those of the police, based on relevant research. Such products should be non-lethal, but allow the police room to handle a variety of situations accordingly and efficiently when needed. The products could be designed in a way that uses colour to indicate what they are, but still enables them to blend in with the uniform. They should be highly discrete, non-aggressive, in a stationary position, and able to work as multipurpose precision tools.

These concepts for possible products could also raise awareness and expand the practices of product designers. The products could be vital resources for the police and enable better approaches to their services, particularly in the case of those that relate to the public as end user. Product design can take the needs in the police-public interaction into account in order to achieve the common goal of a strong trustworthy police and a safe society; and in a sense, make way for another pillar of crime prevention for the police: the public. The public is the police's strongest asset, not only in how they are defended and protected, but in mutual learning and listening. Product design can be a vessel for translating this information into value for the police, and in the end, the public. As Mark Twain said, 'The public is the only critic whose opinion is worth anything at all'.

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# WORKSHOP "PRODUCT DESIGN FOR ELDERLY" IN CHINA: DESIGN EDUCATION AND EXPERIENCE

**Lau LANGEVELD**
Faculty of Industrial Design Engineering, Delft University of Technology

**ABSTRACT**
The summer workshop is held in Beijing, China from 15th of July to 3rd of August 2013 with 32 participants from five different Universities in Beijing. The objectives are getting experienced and educated in product design for elderly during three weeks. Realistic design problems are presented by a Chinese white good company. They expect that the eight product teams will come up with one each product designs. The context of the product design cannot neglect the elderly with their physical fitness and mental constitution. However, a grey movement is going on over the whole world. That is the baby boomers in Europe, one child policy in China and changing family care in India. But the elderly have the money for holding the physical fitness and mental constitution.
Gathering visual design information can be established through hand sketching, photographing, filming and writing. The design teams have made effective use of this information. The abundant visual design information should be structured or ordered. The result of the structuring serves as input of the design brief. Walking design is one of the observation methods that visual design information is capturing with a camera. An aimed walk may observe the design problem or the need of comfort in the available design space. Design competence can be taught with great dedication and enthusiasm for the design profession by practicing knowledge, skill, design, experience and communication. Eight product designs are designed by eight product teams. It is a marvellous result and a tremendous design experience for all workshop participants.

*Keywords: Workshop, elderly, product design, design education, design experience*

## 1 INTRODUCTION

The workshop is held in the summer from 15th of July to 2nd of August 2013 at the Design Research Centre in Beijing, China. The organization is done by the school of Digital Media and Design Arts of the Beijing University of Posts and Telecommunications in the person of associate professor Xiaochun Wang. He has a team of students who are handling the everyday things like lunch, tea and coffee, paper, drawing materials, printer, etc.
Supervising is done by the invited design teacher from faculty Industrial Design Engineering, Delft University of technology and the organizer. The rules are not divided, but they could supervise the workshop optimal with good cooperation.
The questionnaires are held to support our educational goals and to check the experience of the product design teams by filling in the questionnaires.
The progress of the product teams come to expression in the presentation on certain moments of the workshop. Of course differences in progress are noted during the workshop by the supervisors and in the communication with the company. Communication is important part of the design because the designer need evaluation and reflection for a successful product design.
The design process of Pahl and Beitz [1] is adopted for the workshop, but the product teams have to create their own design process based on the archetype and the adopted process.
The educational objectives of the workshop are: knowledge of product design for elderly, knowledge of the design process to create the most appropriate design process, communication with the stakeholders and why walking design apply here. Walking design is implemented here as a new design method, for gathering visual design information of elderly [2].

The results are beneficial for all stakeholders: company, participants, organizers and supervisors. Eight product designs are the results of the efforts made by all the participants of this workshop. For these results, all participants have to communicate, inspire each other, take joint decisions and respecting each individual's contribution.
In the discussion of the experiences of all relevant details will be held against the light. Thus, the power relations are clearly evident, and the effects recorded. The steps have to be taken, cannot stay out of the discussion because they are essential for a successful product design for elderly.
The conclusion may be made that the workshop is ended successfully with eight product designs. Everybody is content with the achieved results, however the company would like more design in depth.

## 2 OBJECTIVES

With the workshop product design for the elderly is experienced for three weeks on the basis of the Pahl and Beitz design process. Product design for the elderly is also the topic of the workshop, but to develop their own design process it is permitted to start with the archetype of the design process. In short, this will indicate an input and an output with in between the design process. The product teams can define a realistic design task this is enabled by a contribution of a company with the workshop topics.
Communication would take place in two ways, first in the form of knowledge and presentation, and secondly in the form discussion and questions. This will happen between all stakeholders of this workshop. However, the hierarchical relationships between company, supervisors, workshop participants and respondent people affect the communication strongly. Communication in the product teams take place on the design contribution of each member that was based on expertise and skill.
Student participants are building on their competence like: design skills, product knowledge, knowledge about the elderly, the design of a specific design process and English skills.

## 3 GOALS

Eight product designs should be the final result of the three-week workshop product design for elderly in the summer of 2013 at Beijing, China. Experience has been gained with the design of Pahl and Beitz to arrive at an appropriate design process for Product Design for the Elderly, but specifically for the educational purposes.

## 4 CONTEXT

Product design for the elderly means: discover where the elderly are capable of. The physical fitness opportunities and mental constitution of the elderly [3] appear miraculously to the young people, who are the participants of the workshop. The question is, "How do you come behind the needs of the elderly in conjunction with their potential." There are two options available: 1) interviewing elderly that has been arranged by the organizers, 2) Walking design, the essential design information gathering is established by observing elderly using a camera for making a movie or pictures.
Product design for the elderly should [4, 5] be searched in several areas: entertainment, household white goods, living room, bathroom, keeping in condition. Entertainment will be used to hold the mentality at the same level, but also in order to achieve improvement of mentality. Improvements will be reached only by a mental activity such as: gaming, brain training, thinking, playing, etc. Household, white goods should be designed in such a way that the decline of physical bending will not influence the design anymore for example: loading and unloading washing machines on the front and at the needed height. Living room appliances are often designed with traditional assumptions that for several years have changed into more comfortable support needs for instance: remote control for lighting, television, audio etc. The bathroom in China will have a big change with aesthetical bathroom design and designing of the appliances, for instance introducing a new way of showering with more comfort and support appliances.
The elderly problem has great attention all over the world [6], because people are getting older and less labour is available. The baby boomers [7] demand special study because they have helped to build their country and their efforts would be rewarded in a good pension facility. In China, the leaders have introduced the one child policy [8] so that the percentage of elderly in the coming years are rising much faster in comparing with the rich western countries. The elderly has good money, but the

financial crises have shrunk it strongly. In China, the children have to take care of the well-being of their parents by a governmental law. Health care will not affordable anymore, because our lifestyle hasn't prevent us from the big diseases in the world such as: cancer, diabetes, obesity and cardiovascular diseases

## 5 GATHERING VISUAL DESIGN INFORMATION

Product design information can be established in a visual way through hand sketching, photographing, filming and writing. This information should be called visual design information. However, the question occurs how to gather visual information design as input for the design process. That should be resolved first. The input determines what will be gathered; this is the first design task in our case, product design for the elderly and the methods of gathering information [9]. The design task includes the gathering of visual design information of the elderly, seeking physical capability and mental constitution of the elderly. The behaviour of elderly people depends strongly on the physical and the mental capabilities. It is almost impossible to realize for all elderly people a vitality description with the corresponding motivation, because each person is unique. Actually, this gathered visual design information should be stored in a database for elderly data.

The design teams of the workshop make effective use of visual design information registration by using a digital camera. The use of a movie camera has not been considered out of piety for the residents of the visited elderly home. Staying close to the topics of the workshop, for instance the topic entertainment may be explored, which delivered a great number of interactions. Just the interaction between a human being and the appliance gives visual design information about the design opportunities.

The output of the visual design information gathering process can be very abundant, but this should be structured and ordered such that the resulting information may be selected for the input of the design problem definition. The design brief, that describes briefly: what, where, how, who, which, etc., follows after the problem definition. The gathered visual design information is also used for writing the design brief.

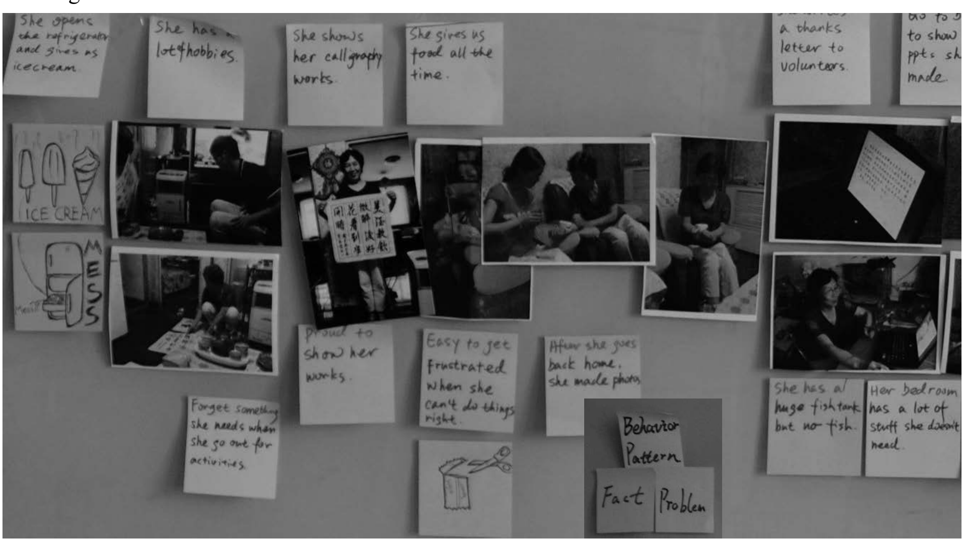


*Figure 1. Visual Design Information ordered with behaviour pattern, facts and problems*

## 6 WALKING DESIGN

During Walking Design, you observe situations that will be the input for a design problem definition. The observation takes place mostly during a walk that is an input of the designer. It will be transformed directly to visual design information by perception or creative action in the mind. This visual design information can be captured with a camera in the form of pictures or a short movie during a walk. The designer stores also this design information plus all conditions in his memory

under which they have been established. This will be a great assistance for the designer at the interpreting of the pictures and short videos to order and structure the visual design information. An interview is another technique of observing, but the main difference with walking design is determining of the strategy and the preparing for an interview. The direction of the interview is established before it starts and the interviewee belongs to the user group. The wondering will certainly not occur in the interview, but it can be happen with the designer while walking. People may observe during a walk, but they also have moments of inspiration and / or amazement. Visual design information gathering will be applied at walking design, because one picture tells more than thousand words and a movie tells more than thousand pictures. This information is dynamically established; therefore the product design proposal should be researched during the orientation phase of the design process. Walking design will be used in the orientation phase of the workshop. However the workshop is organized such as: first week, analysis; second week, synthesis, and third week, realizing product design for public presentation. The orientation phase belongs to the analysis.
Sound walking is an excursion through an environment, while listening is the main goal. The walk may be: at home, downtown, park, nature, factory, workshop, atelier, etc. The similarity between sound walking and walking design is the environment and the walking activity with two different methods of observation. Walking design observes design situations that are established with the mentioned methods above. Sound walking observes the sound situation in an actual place of the environment that is recorded.

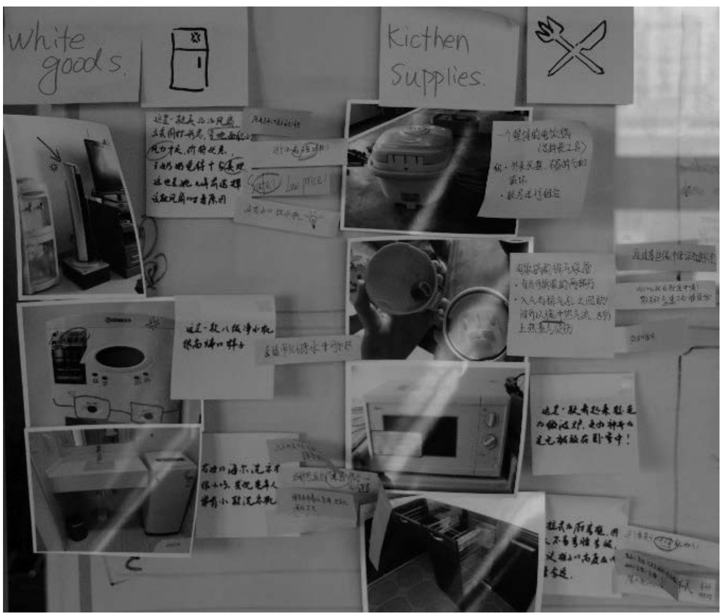


*Figure 2. Ordering and structuring*

An example of the ordering and structuring is shown in figure 2, white goods and kitchen supplies are the ordering parameters. The structuring takes place by activity, place, problem and designer preferences and those are presented with coloured post-its. The visual design information may be established in a huge number of pictures. After that ordering and structuring is a necessity. If the designer ignores this fact, he loses his grip on the design and blocks after some time. The ordering and structuring is an activity that cannot be neglected as a method for interpreting and evaluation of the gathered pictures during walking design.
All pictures should actually be saved with the annotations in a database for product design for elderly that is available to all interested parties. The used and unused visual design information has so much value that storing in a database has sense. This database should be created special for product design for elderly very soon. However the database should be maintained so that the information stays up to date.

## 7 DESIGN COMPETENCE

Design competence covers: design, communication, experience, skills and developing a designer identity. This gives the design its gestalt from the designer who the design task transforms by many creative actions. The design gets its ultimate shape after many product design actions. The product teams have been worked intensively at designing during the workshop depending on the potential: knowledge, skills and motivation. All the product teams have a different potential that will be found back in the completeness of the product design. Designing is communication, it is a statement which should be considered closer. Communication is very broad term that has many points of view of which only some are used in the context of the workshop. Communication in the product teams need to be good but also a high quality has to take place in such a way that everyone encourages each other to a successful design. The background of the product team members can be completely different namely; engineering, art or industrial design, this delivers mostly communication struggles. But the communication with all stakeholders is very complex, everyone has his one interest and significance and show up as student product team, company, education, supervising and organisation. This requires a model of communication that is available for design education projects in cooperation with companies [10]. During the workshop, the communication does not go completely according to the model, there are also the hierarchical relations that play a major role in China. Design experience will be gained in training by participating in design courses, design workshops and design contests. The workshop product design for elderly has many design aspects with which experience may be gained like: elderly in general and in particular mental ability and physical possibilities, identifying needs of the elderly, dealing with a company, design process of Pahl and Beitz, process design out of archetype of the design process, visual design information gathering, walking design, product design, etc. All workshop participants are able to gain their experiences in order to work on their identity through: design skill, knowledge and performance. These properties are for all team members different depending on everyone's personality.

The skills are important for powering the creativity that are transformed into ideas by the product teams, further into product ideas, product concepts, and finally into a product design. Powering creativity also encourages the skills of team members such as hand sketching, generating ideas, developing of concepts, embodiment design, prototyping, testing and evaluating. This can only lead to a successful product design through good communication, presentation and reporting. If a product team comes in a design flow than the design competence grows the fastest in all its aspects. It is always a beautiful experience for a supervisor that his efforts bear fruit for all the participants.

## 8 RESULTS

The results of the workshop will be distinguished in four major contributions such as: product design, questionnaire, education, product design for elderly. Each contribution has its appropriate content for design education which in its totality grows to a mature course in the education of Industrial Design Engineering.

Each product team has submitted a product design report and presented the product design at public workshop presentation. The report provides insight into how the design overall is expired, which has led to some starting points for designing of the design process, “the product design for elderly”. The quality of the product designs vary considerably, these differences emerge as content, justification, opportunities, and advantages and disadvantages during the performance.

Three questionnaires are mailed to the workshop participants at the end of each week. The participants were able to complete this digital survey on a voluntary basis. The questions are to gauge the experiences of the participants of the workshop and the content. In this way, product teams will be followed in the progress of the design process. Besides the participants have the challenge to express their experiences. In the first week the analysis aspects perceived as excellent, walking design is a new design methodology that is well suited to the Chinese way of thinking. However, the participants have experienced the method of disassembling and assembling domestic appliances as. It is an eye opener for all participants, due to the fact that all product components show all design aspects such as function, material, manufacturing and geometry. But they also show their interconnections and relationships for their function as a complete product.

Actually said, it is a product discovery journey. The communication runs with difficulty between the participants and supervisors in the second week. Clear agreements are made to solve the problems, this has put the design process under pressure, but this is good for the quality and progress.

A workshop fits well in an education program of industrial design engineering. An assessment and study credits have to be achieved. It can fit nicely into the electives of the curriculum for the Bachelor and/or Master's program.

Education requires a special design method for Product Design for Elderly, because the product teams should experience the method as efficient and functional in their education. The method is explained in a paper "Product Design for Elderly - Visual design information inspired a new perspective in design education" [2].

## 9 DISCUSSION AND CONCLUSION

The method of walking design will give the abstract thinkers a large number of efforts. On the other hand visual thinkers are attracted to walking design. The design information is easily processed into visual design information that serves as input for the problem definition. Many Chinese people, but also industrial designers are visual thinkers, they all have a great advantage with this method. However, product design for the elderly will require strong commitment from the abstract thinkers to bridge the gap with visual design information.

The cultural differences are clearly reflected in a workshop like this. The place, country, design background of participants, university organization and the company as product organisation, these are the parameters that influence the cultural circumstances of the workshop.

The conclusion can be drawn that eight product designs are a good result of a well-organized and successfully completed workshop. The participants are the biggest winners who have accumulated a positive design experience with product design for the elderly. They have worked hard on their design competence and design identity, of course one is more successfully than the other. The model of product design for the elderly has arisen from various contributions of the participants of the workshop: the eight product design reports one of each design team, the company with their critical comments and opinions, the three surveys and the supervisors with their input on the design process.

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# MUSES IN DESIGN: A COMPARISON OF INSPIRATION TECHNIQUES IN PRODUCT FORM GIVING EDUCATION

**Maaike MULDER-NIJKAMP[1] and Jan CORREMANS[2]**
[1]University of Twente, The Netherlands
[2]University of Antwerp, Belgium

**ABSTRACT**
Defining a products' shape is one of the key challenges for design students in the overall product development process. The formal design of a product determines to a great extend the expressive character and appeal and influences the perception of the product and the appreciation by the consumer.
But before a designer or student designer can actually start to give shape, he or she needs 'inspiration', a vague, mysterious, intangible and hard-to-define phase preliminary to the act of design or visualization of ideas.
This paper reports on a comparative study of the integration of inspirational tools and techniques in form-giving in the design curriculum and projects of the programs Product Development at the faculty of Design Sciences of the University of Antwerp (Belgium) and the program Industrial Design Engineering at the faculty of Engineering Technology of the University of Twente (The Netherlands). The focus of this paper is to get a better grip on the vagueness of those inspiration tools.
The comparative study indicates that there are different types of inspiration tools that will conform to different types of students. Some need a more rational way in getting inspiration, others benefit more from an intuitive approach so they can fully use their creativity. The study leads to a general input-form inspiration - translation – creation - output model where the inspiration techniques are categorized into three distinguished approaches: inspiration tools based on a more systematic approach, an intuitive approach and a contemplative approach. The model also shows different levels to translate the inspiration tools into new product form-giving ideas, based on regeneration (copying elements of the inspiration source), transformation (transforming the elements of the inspiration source into new forms) and interpretation (reinterpreting the inspiration source).
Both institutes integrate rational, intuitive and contemplative techniques in the curriculum, so students get familiar with different working methods. This will help students to get insight in their personal creativity process, and can serve to better diversify future design projects.

*Keywords: Inspiration, Form-giving, Creativity, Rational inspiration, Intuitive inspiration, Contemplative inspiration*

## 1 INTRODUCTION

Should the role of form-giving in product design still be argued, or is it a truism? Multiple authors [1, 2] conclude that the visual appearance of products plays a significant role in determining consumer response, and that good form evokes an aesthetic experience. The number and variation in related studies and the search for methods to initiate and facilitate the form generation process and to verify the outcomes [3] demonstrate the interest in the study of form-giving [4].
In most designs schools, the study of form is integrated and anchored in the educational program. Parallel with a general methodological approach that industrial design and design engineering educational programs initiate to develop products, design institutes also offer a variation of tools and methods to support the form-giving sub phases in the development process. A necessary prerequisite in form-giving is 'inspiration', a vague, mysterious, hard-to-define phase preliminary to the act of design or visualization of ideas. However the initial source of inspiration is often underexposed [5]. Goncalves claims that novice designers tend to stick to a limited array of external stimuli and ideation methods, which could ultimately result in a hindrance to design creativity. Therefore it is important to support

novice students in getting inspired in different ways and learning them to use those inspiration techniques effectively.
The importance of this knowledge of methods, tools and techniques that support the creative process is in line with the statement of neurobiologist D. Swaab, who states that creativity is the ability that someone has to connect (in his head) in a surprisingly and unexpected way old with new knowledge [6]. This paper aims to focus more on the inspirational sources in form-giving than on the generative creativity techniques in ideation and will show an overview of the different inspiration techniques used in the program Product Development at the faculty of Design Sciences of the University of Antwerp (Belgium) and the program Industrial Design Engineering at the faculty of Engineering Technology of the University of Twente (The Netherlands). Both institutes initiate their students a variety of form-giving tools and techniques, spread over different courses in their curriculum.

## 2 ANALYSIS OF THE ACTUAL STATUS

To get a grip on the matter of form inspiration, we inventoried all form-giving related design projects and exercises in our curricula and isolated the form inspiration tool or technique involved. Some exercises are very basic and straight forward, and focus on specific aspects of form like proportion, variation, orientation, order et cetera. Other courses emphasize form ideation techniques like serendipity or synesthesia, and the advanced design projects try to incorporate multiple layers in the form-giving process in order to obtain meaning of form. The analysis of the projects and exercises revealed a certain similarity in design approach. Between the initial design brief (input) and the final result, all designers go roughly through the same stages: a form inspiration phase, a translation phase [7] and finally a creation phase that leads to the final design result (output). This process can be summarized as the IFITCO model (figure 1).

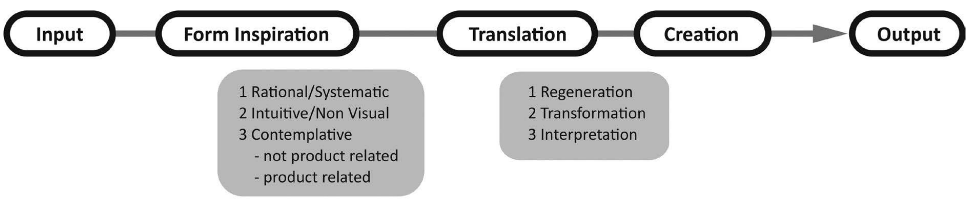


*Figure 1. The IFITCO Model*

## 3 SYNTHESIS - THE IFITCO MODEL

Undoubtedly ideation and (form) inspiration are often linked. Experienced designers think integral, in a way that 'idea' and 'form' arise simultaneously, and not consecutive. But to get more grip on the intangible notion of inspiration, we focus our comparative study on the second stage in the IFITCO model; in order to get insight in how designers cope with form inspiration. By inventorying, discussing and analyzing the form inspiration tools and techniques initiated in both our curricula, we concluded that all these tools can be allocated to one of following three approaches: a rational or systematic approach, an intuitive approach or a contemplative approach (figure 1) [8]. All the approaches will be explained and visualized with examples from both institutes in the next chapters.

### 3.1 Rational or Systematic inspiration tools and techniques

Multiple authors and researchers have reported on rational form-giving methods before [9-12]. What these methods have in common is that they divide the creation process into several stages (of transformation) and that they usually are geometrically based or defined.
The two systematic form-giving inspiration tools initiated in both the institutes, are similar. The first inspiration tool is the approach based on the principles of ‘order and meaning in design’ [12]: ordering and structuring basic volumes, and introducing basic notions of topology, typology and morphology. The second one is the two-step-generation method [4]. This step-by-step approach starts from geometric volumes. By simple manipulations and variations in surface orientation the method offers the possibility to generate a number of form alternatives (figure 2).

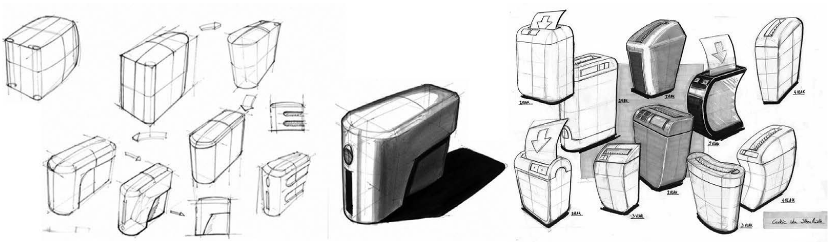

*Figure 2. left: Two step manipulation method applied on a game console (Twente_Thomas Houwers); right: Two step manipulation method applied on a design for a paper shredder (Antwerp_Cedric van Steenkiste)*

### 3.2 Intuitive inspiration tools and techniques

Although Goldschmidt and Sever [13] speculate that visual stimuli are possibly more effective than textual stimuli, non visual inspiration sources can also be useful to designers to build up their own stocks of form-finding techniques. Intuitive inspiration techniques let students discover their own personality, teaches them to follow their own intuition in creating novel product forms and gives them confidence in making decisions based on the inspiration source. Intuitive inspiration tools incorporated in the design projects of both institutes are: serendipity, silhouette drawing, synesthesia, music as form inspiration tool, taste as form inspiration tool etc. Al these techniques use non visual stimuli to create new forms. The left picture of figure 3 shows us the serendipity technique, defining a product form based on a group of random sketched lines (Antwerp), the right picture shows us the integration of drawing black silhouettes to create new product forms from scratch (Twente).

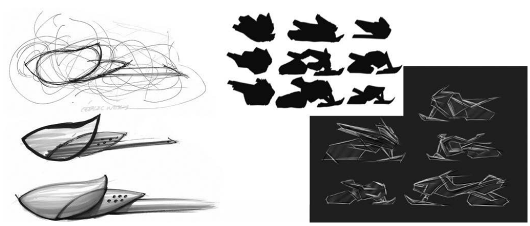

*Figure 3. Left: gas lighter sketches using the serendipity form giving inspiration technique (Antwerp); Right: Snow scooter sketches using the silhouette form giving inspiration technique (Twente).*

### 3.3 Contemplative inspiration tools and techniques

Research on the designer workplace [14] has shown that designers use existing images and photos (and other rich visual material), pasted in moodboards and collages as generative tools. The relevance of collecting visual material as inspiration tools for designers is extensively argued by multiple authors [14-16]. Design research has also demonstrated empirically that exposure to visual stimuli at the conceptual search phase in designing has a positive effect on idea generation in terms of the judged creativity of preliminary solutions [17, 18]. The definition of ‘contemplative approach’ was chosen because the production of these visual data is a carefully considered act in the design process.

Depending on the specific goals set by the design assignment, or the stage in the form-giving ideation process, students of both institutes compose moodboards and collages as generative tools in the process of form-giving. These moodboards can show abstract, not product related images like e.g. nature, textures, materials, spheres, or concrete, product or artefact related visuals like Form/style analyzing collages, brand analyzing collages or a set of images for a ghosting technique.

The nature of the collage or moodboard can lead to different design translations: abstract sources tend more to interpretation (an interpretation of the abstract visual stimuli), while e.g. a Form/style collage could more easily lead to regeneration (copying style characteristics of the visual stimuli) or transformation (translating the style characteristics of visual stimuli into new forms) in the design results [7]. Since moodboards and collages are most commonly used by designers, it was no surprise that we determined a large mutual equality in the integration of these techniques in the two design programs. Figure 4 illustrates two visual input tools of the contemplative approach that the institutes have not in common. The scheme in Figure 5 summarizes all of the inspiration sources applied in the design curricula of Antwerp en Twente. Apart from the techniques initiated in our projects, there are undoubtedly various other form inspiration tools and methods (eg periodic table of forms [9]), but in this paper we limited ourselves to those that are offered in our curricula.

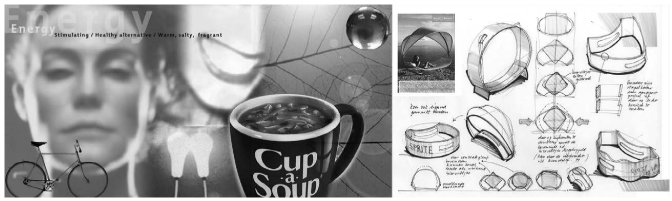


*Figure 4 Left:Vision moodboard of abstract images (Twente); Right: Image based Serendipity (Antwerp)*

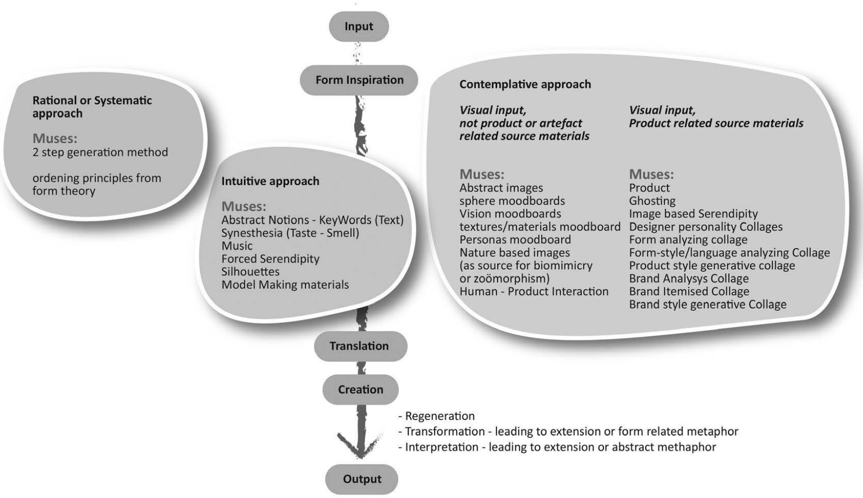


*Figure 5. Survey of the inspiration tools and techniques initiated in the institutes*

## 4 DIFFERENT TYPES OF STUDENTS

The survey in figure 5 visualizes up to 25 different inspiration techniques which are currently integrated in the design education of both programs. The comparison of the results shows that there are different types of inspiration tools that will conform to different types of students. Based on our teaching experience, one could say that the rational or systematic form generation or inspiration tools are easy to teach, easy to learn and easy to apply, thus well suited for novice design or engineer students. According to Dorst [19] novice designers do not have a lot of experience and benefit more from a structural approach. Well balanced in composition and proportion, the outcomes of these rational inspiration tools can have high aesthetic appeal and value, but most of the time the results are poorer in expression, emotion or underlying meaning.

Students with a preference for intuitive inspiration tools have more affinity with art and like to work in a less structured way. The design process of those students can be really chaotic while searching for different opportunities to define a product shape. Figure 6 Right illustrates the exploration and manipulation of a material to form the perfect design. The outcome of the intuitive tools is a process of trial and error and can be really innovatory and powerful, but can also be poorer in expression, emotion and underlying meaning. The uncertainty of the outcomes could be a disadvantage for students who like to work in a more structured way.

Students who are more common with creating a framework as starting point for the design of a product are more familiar with the contemplative method. Those students get inspired by defining a certain starting point to design their product (for example a collage with a specific style). While comparing and discussing the outcomes of different design assignments, it became clear that in most cases the contemplative method fits well for industrial design students. The outcomes are more reliable compared to the intuitive approach and this method seems to lead to more meaningful designs, because it is based on visual analyses of a collage which in most cases forms a story to discuss the design of the product. Figure 6 shows two results of a first year design assignment. Students were asked to design a lampshade in polypropylene sheet based on their own inspiration sources. The outcomes of this case show the difference in approach between students. The left student is using a contemplative approach as main inspiration source; the other student uses a more intuitive approach by exploring and experimenting with the sheet material.

*Figure 6. Left: Contemplative approach: Form-style analyzing collage as inspiration tool for a polypropylene lampshade design (Odille Grillet); Right: Intuitive approach: experimenting with polypropylene sheet material as inspiration for a lampshade design (Nick Janssens)*

## 5 DISCUSSION

Using different inspiration sources does not guarantee successful products, nor does the application of form inspiration techniques automatically lead to aesthetic outcomes. It is not because a form shows expression or reflects a certain meaning, that the aesthetical qualities are perceived to be superior. By analyzing the design results of both institutes it became clear that the three different approaches lead to different outcomes. This was well illustrated by the design project of the polypropylene lampshade: different types of students use different approaches leading to different kinds of results. The rational inspiration sources tends more to the regeneration and transformation level, the intuitive approach in this design challenge tends to spatial ingenuity, while the contemplative approach leads to more profound designs that in most cases tell a certain story.

## 6 CONCLUSION

The joint analysis of the integrated inspiration tools and techniques in form-giving in the design projects and exercises gave us a good overview of which techniques are applied in the institutes of Twente and Antwerp. Both schools integrate a rational, intuitive and contemplative approach in the curriculum, so students get familiar with different working methods. This will help students to get insight in their personal creativity process, and can serve to better diversify future design projects.

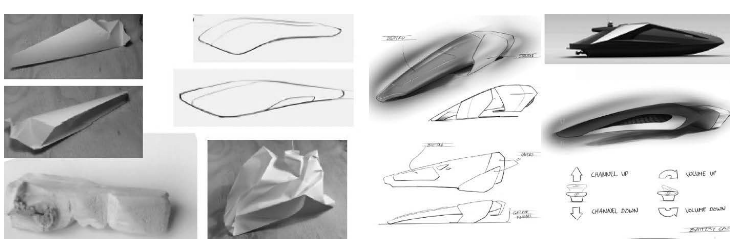


*Figure 7. Design process of a remote control combining the rational, intuitive and contemplative approach (Ruben van den Hout)*

Although we can't deny that in most cases students prefer one of the approaches above the others, falling back on their preferred inspiration technique may have a restrictive effect. The high potential students however are able to integrate the systematic, intuitive and contemplative approaches (figure 7) and can easily diversify between the different techniques. The initiating and the control of a variety of form inspiration techniques from different approaches can provide a broadening effect and stimulate creativity in form-giving. The more different tools and techniques the designer masters, the more he or she can vary his/her designs.

Teaching experience taught us that the most appropriate students to study Design Engineering are rational students with an artistic touch and a focus on a contemplative approach, because they are able to consciously choose the best tool or technique and are able to switch between intuition and ratio.

In the future it would be interesting to test novice students at the start of their study, and to see whether the more extreme artistic or rationally oriented students evolve through their education to more complete design students mastering all three of the approaches.

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Chapter 7

# DESIGN EDUCATION IN BUSINESS AND INDUSTRY

# DESIGNERS IN DESIGN THINKING

**Erika BRAUN, Jessica MORELAND, Emma SANDERS and Carolina GILL**
The Ohio State University, Department of Design

**ABSTRACT**
Design thinking has been a popular topic among the forward-thinking technology and business scenes. Even universities have joined the trend of adopting design thinking as a tool for innovation. While its popularity has opened up new and exciting opportunities for all design professions, when design thinking is packaged as a strategy to deliver innovation it is often implemented like a linearly gated step-by-step process. Thus the value and effectiveness of creativity offered in design thinking is weakened and the results are incremental at best. In these cases, designers, design consultancies, educators as well as business strategy firms have separated the **tools and methods** of design thinking from the **mastery needed to use them**. A designer's creative process is iterative, messy, uncertain, and often leads to failed attempts and frustration. These characteristics are inherent to its organic nature, but ambiguity and learning from failures often lead to opportunities to innovate past the comfort of certainty and status quo**.** In an attempt to develop an organized and reliable design thinking process for the business culture, we have diluted the role of the designer as the expert capable of navigating, managing and leveraging opportunities from the creative challenge. This design mastery is a necessary component to successful innovation teams just as much as mastery with analytical tools and processes, verbal communication, technology and business. This paper offers insight into the adoption of design thinking at a large university in the United States. The authors interviewed students and faculty from Design, Engineering, and Business who have participated on multidisciplinary teams seeking innovation. Though disciplinary tools and methods are successfully borrowed or adapted within multiple fields, this paper suggests that the discipline-based mastery of skills is essential for those tools and methods to be used to their fullest potential.

*Keywords: Design thinking, innovation, industrial design, disciplined based expertise*

## 1 INTRODUCTION

In today's globally competitive world, universities and businesses strive for innovation in order to achieve a competitive advantage. A focus on alternative approaches has sparked new interest in creative fields, and over the past decade, businesses have been using design tools and methods as part of their innovation strategies [1]. Subsequently, the practice of 'design thinking' has become complementary to analytical business processes and a desirable approach to innovation that addresses "wicked" or complex problems [2].

But what is design thinking? Do you have to be a trained designer to utilize the approach? Multiple definitions and models have emerged in the last decade. The models discussed in this paper are based on varying design applications and utilize theories and tools from multiple fields including product design, psychology, and anthropology. To begin, Johansson-Sköldberg, Woodilla and Çetinkaya outline a distinction between 'designerly thinking' and 'design thinking.' The authors suggest that 'designerly thinking' refers to the practical skills and innate competencies of a designer and is "rooted in the academic field of design." On the other hand, 'design thinking' refers to the use of design practices and competencies by disciplines outside of design. [3] Similarly, for Roger Martin, design thinking is a distinctive approach that businesses need to use to dive into unknown territory and "solve new heuristics."[4] Design thinking from this perspective is about borrowing designers' ways of thinking and working in order to promote innovation in businesses, as well as balance the analytical business mindset with the intuitive and creative design mindset. Tim Brown, CEO and president of IDEO, is also a proponent of using design thinking in business but he defines design thinking as the "human-centered approach that designers use in the development process". He believes that "drawing from the designer's toolkit allows businesses to better integrate the needs of people, the possibilities of technology, and the requirements for business success" [5]. While all of these definitions of design thinking endorse the use of designers' tools and methods as a valuable asset in the innovation quest, one thing that is not clear is the role of the designer in the design thinking process. Brown suggests that the traditional role of designers designing products is *"tactical"* and the results are limited in terms of value creation; in contrast, the role of designers at the front end of the design process, before the design and development opportunities have been identified, is *"strategic"* and leads to dramatic new forms of value. [6]

Most designers agree that the popularity of design thinking has opened up new and exciting opportunities for the profession. Many design consultancies have changed their focus from product design to strategic design and are exploring new meaningful areas of application that have significant societal impact. Business strategy firms as well as business schools have embraced design methods and have developed entire programs around design thinking, but the effectiveness of these methods has been put into question. According to Brian Ling from Design Sojourn, "design thinking has not produced the results that business has been hoping for, and despite the best efforts, design thinking will continue to be something only a few can do well. Furthermore, design thinkers that have not been classically trained in design "doing" will likely not realize that great innovative solutions do not come at the end of the process; they come from any part of the process. Design is an iterative activity that only has broad guidelines but no fixed process. What's more important is that critical insights, sensitivity to consumer needs and beautiful solutions come from the creative chaos encouraged by an open design process. All of this got killed when the business mindset required design thinking to have structure, repeatability, and reliability." [7]

The researchers believe that designers, design consultancies, educators as well as business strategy firms have separated the **tools and methods** of design thinking from the **mastery needed to use them**. A designer's creative process is iterative, messy, uncertain, and often leads to failure and risk taking. These characteristics are inherent to its organic nature, as ambiguity and learning from failures often lead to opportunities to innovate past the comforts of certainty. Because the process involves both "problem solving" as well as "problem setting", an analytical approach that relies on a prescribed set of methods often leads to unsuccessful results. By redefining the given problem, the goals, and the means by which to achieve those goals, the problem expands and the process changes [8]. As a result, designers continually adapt their processes in order to manage the instability of a problem. So in an attempt to develop an organized and reliable "design thinking process" for business, the organic processes used by successful designers have been diluted. Designers are trained to expertly navigate and leverage opportunities from the creative challenge, and that design mastery is a necessary component to successful innovation teams. This paper explores mastery in engineering, business, and design, and specifically addresses the value that the design mastery of tools and methods adds to the design thinking process. The paper also addresses how design mastery enhances the 'strategic' role that designers can play in the front end of the design process.

## 2 DESIGN MASTERY WITH TOOLS AND METHODS

Design mastery is found in the practical skills and innate competencies of a designer. Designers are trained to frame problems and reason through abductive thinking [9] in order to solve problems in new ways and create products that serve the people who use them. The process of problem solving and creative thinking is engrained in the practice of design, where tacit knowledge plays an important role [10]. Beginning in the foundations of design education, future designers are taught and encouraged (through practice) to see problems from multiple viewpoints and approach them through different strategies. These thinking strategies help designers build a framework [9] within which they are taught to "see" things differently, to play, to experiment, and to physically manipulate objects and forms in order to gain a better understanding of how things work, how people interact with things, and how to generate new possibilities. From the moment students are accepted into design school, they are immersed in an environment that rewards experimentation and encourages them to question the challenges presented to them. One of the initial goals of foundational design projects is to break the mindset that is developed through secondary education where there is a "correct" answer and that there is a completely objective way of evaluating work. The process in which students are able to identify opportunities from ambiguity takes time, and occasionally some students are so uncomfortable with the 'moving target' that they switch programs early on. The ones that recognize opportunities in this organic process often thrive in this environment.

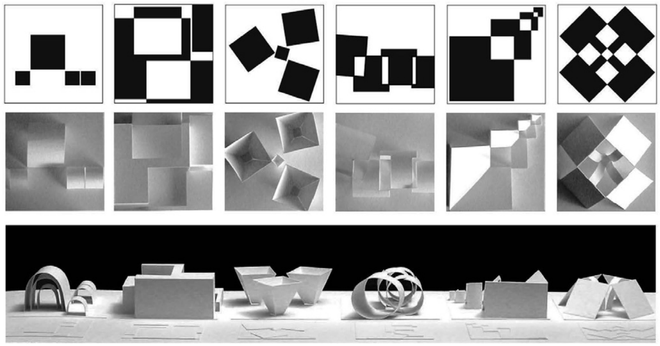

*Figure 1. What is the 3D object described by the 2D projection?*

This process is also systematic; it typically begins with short exercises that allow individuals to discover sophisticated ways of “seeing” and understanding form (Figure 1). Then the exercises focus on developing refined skills in generating and representing an object (Figure 2) and gradually evolve into more complex exercises and problems that address issues from materials to manufacturing processes to ergonomics to envisioning future experiences for people (Figure 3).

*Figure 2. Multiple representations of a concept for a child resistant spray bottle*

While the initial perception of Figures 1, 2 and 3 is about the “pretty” illustrations, each one of them is a visualization that represents a different level of complexity in terms of the problems being addressed. The challenge addressed in Figure 1 is to understand projections, proportions, materials and form, the challenge in Figure 2 is to develop a physical concept through different materials and levels of resolution, as well as testing the results, and the challenge in Figure 3 is to identify a need for a service, researching the environment, evaluating alternatives and proposing a complex service that can alleviate the stresses of being a student parent.

*Figure 3. Future Scenario of a University Service for Student Parents*

The tools used to arrive at these images are typically not deliverables, so it is easy to see the final “form” of the artifact as the primary output and the visualization or form giving as the main value offered by the designer. Expertise in form development and visualization eclipses the mastery needed in arriving at the insights that lead to the development of the new “form”. Typically the “form” has a very well defined function that is directly related to the users’ needs. The process that leads the designer to this form is messy, uncertain, unstable and unique. The research and design “toolkit” used in developing the child resistant spray bottle from Figure 2 included mind mapping, sketching, prototyping, testing, 3D modeling, focus groups, observations, interviews, etc. To effectively manage, analyze, and evaluate the information gathered and the ideas generated by the group of designers, expertise in the use of these tools was necessary in order to develop an original solution. These same methods are used in "design thinking" when the application, or problem, takes designers outside the realm of products and physical "form". The need for mastery with the "toolkit" is not as obvious to other disciplines but the capacity to comfortably manage the uncertainty and "messiness" of using the many components of the "toolkit" is the same, regardless of the application. Therefore, in any design project, the designer plays both a "*tactical*" and a "*strategic*" role throughout, which benefits the final outcome or solution.

## 3 INNOVATION AND DESIGN THINKING IN HIGHER EDUCATION

Seeing the value in producing design thinkers, many universities have begun embedding design-thinking practices into their engineering and business curriculums. At The Ohio State University, this training looks very different across disciplines, as design thinking is modified to meet varying disciplinary demands. To add to the variability, self-help-style books describe hundreds of tools and methods and present design thinking as a strategy for product innovation and business innovation. However, these tools and methods are often removed from the design mastery needed to excel in the design thinking process. As a result, some of the complexities and nuances of "design thinking" are lost in translation, and the results can be limited. A trained designer offers a clearly unique thinking approach to the complex practice of design thinking.

At The Ohio State University, the best examples of innovation-driven courses at the undergraduate and graduate level often bring together students and faculty from Business, Design, and Engineering. Collaboration between disciplines is encouraged, be it a highly specialized project led by mechanical engineers, or an explorative research project led by designers. Members from all three disciplines often use a type of design thinking in the early stages of a project, whether a project is collaborative or not. As a result, in a collaborative setting, the value of design mastery in design thinking is seldom recognized. When designers are invited to participate in multidisciplinary projects their "tactical" roles are frequently called upon, however, their mastery with design thinking and "strategic" roles are underutilized—even when design thinking is being used.

To gain a broader understanding of how design thinking is being adopted into the curriculums of Business and Engineering programs (including mechanical, human factors, and computer science), the authors (a team of design graduate students) conducted interviews with fourteen students (both current and former) as well as six faculty across the three disciplines in question: Design, Engineering, and Business. Participants were asked to describe the value they thought students within their discipline and the other two disciplines brought to group-based projects. During the interview process, participants were also asked to diagram and/or describe the process they go through when trying to solve a problem, shedding light on the "innovation" process and associated methods used by each discipline. Because of the small number of participants, the results of the study are of limited significance, but the qualitative data was useful in understanding the way in which students and faculty perceive their expertise and the value of other disciplines.

By comparing how the members from each discipline responded, the research team was able to gather insights into the skills, processes, and mindsets inherent to each discipline and their general perceived value. It was clear that each discipline offers unique skills and proficiencies, as well as a somewhat predictable way of thinking about a problem. To analyze the survey results, the research team separated answers from Engineering, Business, and Design and coded similar responses. The results offer a summarized self-description of each discipline's creative process and competencies followed by their value as perceived by the other two disciplines.

The engineering students expressed a common focus on accuracy, precision, and reliability, and believed these strengths to be valuable in all stages of the design and development process. Participants in both design and business believed that engineers offered a high level of expertise and a practical approach to the decision making process. All team members perceived engineering processes as established, repeatable, and well defined. The engineers felt most at ease when dealing with physical and technical constraints, and believed that focusing on a workable solution was more important than continuing to explore possibilities or reframe the problem. These findings suggest that engineering training is abstract, intuitive, deductive and sequential, and focuses on optimizing solutions within a given design challenge.

The business students expressed a common focus on communication, creativity, analytical thinking, reliability and repeatable processes. These students believed their strengths to be important for understanding the market as well as identifying and communicating unique and marketable solutions that create value for the consumer. Team members from engineering and design viewed business students as leaders who were capable of seeing the larger scope of a project and keeping the team on schedule. Business students were also viewed as analytical and the go-to person for understanding and optimizing the economic value of a project. These findings suggest that the characteristics of thinking styles taught in MBA programs allow the business professional to bring big-picture managerial skills to the design process.

Finally, the design students expressed a common focus on creativity, visualization, process flexibility, and continual iterations of new ideas (reframing problems, building upon and improving ideas through prototyping). Designers reported that their training focused on making connections and finding patterns, as well as being encouraged to create, take risks, and experiment. The other disciplines viewed designers as creative visualizers who were able to make connections from research and make decisions based on users' needs. These findings suggest that a designer's training in empathy, divergent and convergent thinking, tolerance for ambiguity, as well as concept iteration allows designers to take risks while developing meaningful creative solutions.

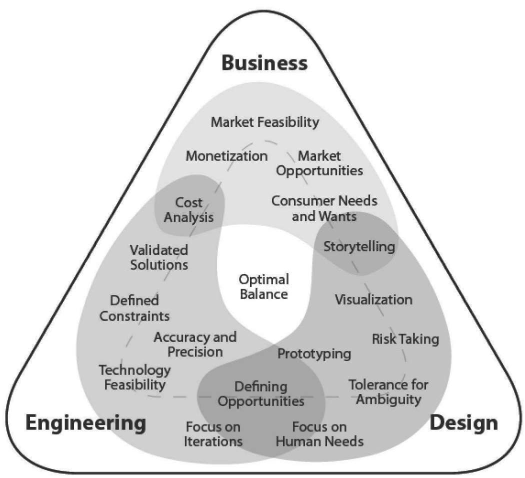


*Figure 4. Discipline Based Mastery for an Effective, Balanced Innovation Team*

The research findings provide a unique perspective of the perceived value each discipline brings. After reflecting on these differences, participants were also asked if they preferred working in multi-disciplinary teams or teams with people from their own discipline. The overwhelming response was that working in multi-disciplinary teams offered many advantages, and the optimal disciplinary make-up of the team depended on the project. Inspired by the research findings, the above diagram (Figure 4) illustrates the relationship between the three disciplines and the value each discipline brings to an innovation-driven project. Some of these disciplinary skills or masteries are overlapping, but each discipline offers a very distinct role in the design development process. Project needs may lie anywhere within the framework, and depending on the project, certain disciplinary tools and methods may be more appropriate or heavily weighted. However, complex multi-dimensional projects typically benefit from an optimal balance of all three disciplines.

## 4 CONCLUSION

Although students in Business, Engineering, and Design all use design thinking tools and methods, non-designers typically do not use them to their full potential. As noted in the interviews, business and engineering students use a deductive, linear, and repeatable analytical process. Designers practice a more open-ended, abductive thinking approach that can be challenging for non-designers to adopt. The designer's mastery is critical when using the tools and methods from design thinking.

In addition to the mastery with their tools and methods, the "*strategic*" role designers are able to play makes them a valuable asset during the early stages of any innovation endeavor. Designers can be most valuable within multi-disciplinary team projects when they are addressing open-ended complex problems. Unfortunately, designers continue to be more frequently called in to contribute with aesthetic and form development skills—in their "*tactical*" role. The distinct "*strategic*" skills and design mastery of the trained designer in the early stages of design development are currently undervalued.

While it is clear that designers have not been effective in conveying what design mastery entails, the larger problem may be that the adoption of design thinking and improper use of the tools and methods threatens the future of design and the credibility of designers. There is a need to better communicate the value of design mastery with the methods in design thinking, but there is also a need to develop complementary methods that can combine empathy, analytical and intuitive, deductive, inductive and abductive approaches that allow all three disciplines to equally participate in the innovation process.

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# HCD IN A QUASI-MARKET: LESSONS FROM A DESIGN PROJECT IN KEBRI BEYAH REFUGEE CAMP, ETHIOPIA

**Kathinka HASSELKNIPPE, Gudrun REIKVAM and Brita Fladvad NIELSEN**
Department of Product Design, NTNU

**ABSTRACT**
A student design project conducted in a refugee settlement in Eastern Ethiopia during fall 2013 illustrates the challenges of designing appropriate products and systems for the humanitarian market. The presented case study involves the distribution of ethanol stoves within the Kebribeyah refugee camp. The students discover the challenges facing the designer within this humanitarian market. They identify the market as a quasi-market in where the end-user is not the customer and this leads to added parameters being relevant for the design process. There is a gap in applicable methodologies when designing for markets where the purchaser is not the end-user and has no influence on the product selection or feedback and where the opportunities of cooperation are limited due to the nature of humanitarian relief. The aim is that observations from Ethiopia together with existing human centred design theory can advise designers on how to best go about designing for the humanitarian market.

*Keywords: Humanitarian design, Ethiopia, design methods, quasi-market*

## 1 INTRODUCTION

A “humanitarian market” for off-grid renewable technologies has emerged and with it a need for well-fitted products and services. The humanitarian market can be defined as “the market created between humanitarian actors and suppliers to fill the need of staff and beneficiaries” [7]. A humanitarian market emerges in the aftermath of a crisis, such as natural or industrial disasters, national or international conflicts. Every humanitarian market is heavily represented by international and national non-governmental organizations (NGOs). Other factors include donors, service providers and enterprises that develop, purchase, and distribute goods such as food, shelter, medical equipment, and energy generating devices [6]. In the humanitarian market the customer is defined as the purchaser of the product or system and the end-user as the person aimed to be using the product or system. This definition will be used throughout the rest of the article. The humanitarian market can be compared to a quasi-market that is established and maintained by the public sector, services produced in quasi-markets usually implement the objectives of social profitability and welfare, the public sector is usually the subscriber, regulator, and purchaser of the service. Public sector is here comparable to the United Nations and donor countries' role within the customer-supplier relationship.

At the end of 2009 there were more than 10 million refugees in the world [1]. People become refugees as a result of war between countries, civil war and persecution from religious or political reason, famine or other natural disasters. About 80 percent of refugees come from developing countries and most refugees remain relatively close to their home region, fleeing to neighbouring countries or even within their own country. About one third of the world’s refugee population lives in refugee camps. Refugee camps are temporary communities built to provide shelter and aid for refugees. Camps are intended to be temporary solutions, with the repatriation or resettlement of refugees as the ultimate goal. However, because of ongoing conflicts most refugee camps end up becoming more or less permanent settlements, often merging with local communities in the surrounding area. In fact, the average refugee spends 17 years living in a refugee camp[2]. Aid given to refugees is paid for by donations from public fundraisers, governments and UN funds. This money is normally channelled through NGOs, the UNHCR or the public sector in the host country. Humanitarian crises may emerge or change rapidly and the organizations operating within it need to master operating within this uncertainty. The big challenge might not be the lack of resources, but rather how to use them within these dynamic environments with the best possible outcome [3]. Prolonged humanitarian crises, where whole populations rely on international financial support, will result in donor fatigue [7].

### 1.1 Research gap and approach

There is only a limited amount of literature available regarding design methodology for humanitarian markets. The starting point is that the humanitarian market can be referred to as a quasi-market, meaning that it is a situation where the efficiency of the free market is combined with public administration and funding. Quasi-markets are created when the public sector opens its own service production to other producers by abandoning its monopoly and hierarchical way of producing services. The main purpose of quasi-markets is to raise competition between existing or potential providers, which may be private or public, for profit or non-profit organizations[4], 2004).

Due to the practical approach of the project, the literature review was therefore primarily based on research from similar contexts and human centred design approaches. Even if this might prove to be helpful, it has its limitations.

Human-Centred Design (HCD) is a process and a set of techniques commonly used to create products, services, environments, organizations and modes of interaction [5]. The HCD toolkit from IDEO is presenting the three lenses that needed to see the world through in order to achieve a successful human centred design process; desirability, feasibility and viability. In this design project and case study the HCD methodology has been considered as well the three factors when looking at other designs in the humanitarian market. This approach has been created by the developed world designing for the under-developed and developing world. The perspectives presented might therefore be both biased and not contextually fitted. Furthermore it is not aimed at the humanitarian market and as a consequence will not consider the issue of the end-user not being the customer. A participatory design approach is often used to extract information and knowledge from a community, even though the result of this research could only be for the benefit of project planning and upwards accountability to donors and not contribute to the community directly [13]. However, most projects are reliant on and will greatly benefit from a thorough information gathering process in order to provide a detailed problem description. Processing the gathered information in a good way will also help designers provide the most fitting solution and thus hopefully avoid the problem of failing pilot projects [6]. The HCD IDEO toolkit emphasizes that for a human centred design to be successful there are three lenses that need to be fulfilled: desirability, feasibility and viability [4]. Still, refugees are not accessible for end-user research and are currently not considered during the product development process [7]. Nielsen and Santos' [8] consider the top priorities of a product from the product development enterprises point of view to be safety, manufacturability and robustness. Whether this is the viewpoint of the end-user is uncertain.

This case study will contribute to expanding knowledge on what the contextual needs within this market are and to shed light upon the challenges a designer might face in the humanitarian market. There is a gap in literature when it comes to designing for this market and based on the design project in Ethiopia.

### 1.2 Methods and scope

Six days were spent researching in Kebribeyah refugee camp and the surrounding area. During the first visit the main goal was to understand the end-users need for off-grid energy solutions in regards to cooking as well as achieving a greater understanding of their cooking habits, culture and environment. Five semi-rigid interviews with refugee women were completed, each interview lasting about 45 minutes and conducted in the setting of their homes. Later, a group discussion with three of the former interviewed women was conducted. Key informants in the camp were also interviewed, including but not limited to: field staff from Gaia, United Nation High Commissioner for Refugees (UNHCR) and Administration for Refugee and Returnee Affairs (ARRA) officials and incentive workers amongst the refugees. A structured interview with Abdirizak Mussa-Eid Ardaale, one of the field staff from UNHCR was added were we requested him to prioritize what he thought to be most important when implementing a new product in Kebribeyah refugee camp. During the second trip we visited the two other camps in the area, Sheder and Aw-barre, and made a second visit to Kebribeyah. This was to see the similarities and differences between them as well as different projects that already had been or would be implemented. We also observed the refugee women cooking injera, their regular breakfast dish. Follow-up research and interviews were conducted in the capital of Ethiopia, Addis Ababa and finally a two day visit to the University of Mekele. These interviews were done based on a snowballing sampling technique[9]. In Addis Ababa we met with many different stakeholders; these included Horn of Africa Regional Center/Network (HoA-REC/N), Gaia, Danish Refugee Council (DRC), Save the Environment Ethiopia (SeE), local and national governmental agencies and different branches of the UNHCR.

## 2 DESIGN CHALLENGE, CONTEXT AND OBSERVATIONS

Kebribeyah is a refugee camp run by the United Nations High Commission for Refugees (UNHCR) in collaboration with the government arm responsible for the implementation of refugee protection and assistance activities in Ethiopia; the Administration for Refugee and Returnee Affairs (ARRA). Kebribeyah was constructed in 1991, and today has a population of almost 16,000 Somali refugees [10]. The design challenge was to design an alternative solution to provide off-grid energy solutions for refugee camps and one of the first steps of the research was an eight weeks field study in Ethiopia. The research took a starting point in a case study for the distribution of ethanol and ethanol stoves in Kebribeyah refugee camp in eastern Ethiopia. Upon arrival the refugees are provided with basic supplies such as pots and pans, tarpaulins, wood for constructing shelters etc. A non-governmental organization (NGO) called Gaia Association[11] has been providing the households in Kebribeyah with ethanol stoves since 2005 and currently distributes ethanol.

The aim of the design project was to assess the possibility of designing an improved stove design, but due to the contextual insights retrieved, the result of the project became the design of a system and products that supports local fuel availability and self-reliance as a compliment to the Gaia project.

### 2.1 Fuel access

During the visit it was discovered that the supply of ethanol is insufficient and the refugees still rely on the use of charcoal and collection of firewood in order to cook their meals. Refugees had been provided with four different stoves in addition to the Gaia Ethanol stove[11] and it was only after talking to the women that the students realised that their main concern was fuel access, not stove design. Only a sixth of the ethanol needed was available and the women were forced to still use fossil fuel. This information is not available on any fact source identified.

### 2.2 Multiple stakeholder agendas and power relations

It was discovered that stakeholders affecting stove use and fuel distributions include refugees, UNHCR, ARRA, but also the local community and government, donors and NGOs like Gaia Association, the Ethiopian government and citizens, manufacturers of products used in the camp (like Dometic), other smaller NGOs and international organizations such as USaid. There are some challenges connected to a multiple stakeholder environment, amongst others complex power structures and multiple stakeholder agendas and the design solution depends on the relationship between all of these. Understanding these structures in the case of Kebribeyah is a demanding task. The first impression was that the relationships between the different stakeholders in Kebribeyah are unclear not only from an outsider's perspective, even the stakeholders themselves struggled when attempting to explain the complex power structures. In particular, the relationship between ARRA and UNHCR is challenging to map out. For instance, in order to be permitted entrance to the camp the students needed to explain the project's intentions with three levels of UNHCR and ARRA separately. UNHCR was always the first office visited and they decided whether or not they would encourage ARRA to approve the visit. All stakeholders have their own "entry point(s) and criteria for participation" in humanitarian operations (Bellenca & Garside, 2013). Further, ethnic and cultural power relations affect the success and acceptance of a technology and a system. Ethiopian and Somali culture is fundamentally hierarchical and vertically oriented. (IDMC, 2004; Gundel, 2006). This was apparent in most social settings and formal meetings attended. In Kebribeyah these hierarchical structures appeared in many ways. They were present within each organization, within the refugee community as well as shown in the interaction between the refugees and staff from the different organisations. When conducting the research the students got the impression that permission given from camp officials gave us a "free-pass" to act in ways which would be considered intrusive, such as photographing the refugees and entering their homes. The refugees seemed to have little authority over these decisions, even if they were not forced to accept visitors they might have felt obliged because of their gratitude towards the organisations providing for them. Traditionally, clan structure is the main foundation for the pastoral Somali society [12]. Governance in the Somali region of Ethiopia is a complex relationship between state and traditional institutions, such as councils of clan elders [13]. The students believe these social structures also play an important part in the lives of the Somali refugees in Kebribeyah. This was pointed out to us by one of the UNHCR officials of Somali descent, who advised us that in order to gain support for the project amongst the refugees, involving the elders and the most respected women would be a good move. However, Bloom and Betts argue that there is a fear that participatory methods may enhance existing power structures within communities instead of empowering those who are the most marginalized [14].

### 2.3 Short-term thinking, long-term settlements

Many refugees have been resettled to other countries but the majority will most likely spend several more years in Kebri beyah. In spite of this, many of the refugee met expressed a hope to be resettled to the USA in the near future. One of the women interviewed had just had her application declined and even though some of the younger refugees had grown up in the camp, it seemed they were considering it a temporary home. Most international organizations working in the humanitarian market operate with annual or biannual budget terms. For local partitions of these organizations, long term planning is therefore a challenge. Stakeholders explained that short-term objectives and long-term thinking collide in these chronic emergencies. When Kebribeyah refugee camp was established the priority of UNHCR and the government was to cover the basic needs of the refugees: food, water, shelter, sanitation and health care as in all crisis situations [1]. Other, more long-term solutions were not a concern. In order to cook their food, the refugee's harvested wood from the surrounding trees, which has led to complete deforestation of the area. As a result of the deforestation, fuel for cooking has received more attention and for the last 7 years Gaia Association has worked on providing ethanol as an alternative fuel for cooking. Unfortunately the supply of ethanol does not nearly cover what is needed, so the refugees still rely on collecting firewood.

### 2.4 The role of pilot projects

The Save80 stove was designed to save 80 percent of firewood. The system consists of a specially designed stove with pots that fit perfectly. It also comes with the wonder-box, a Styrofoam insulation box designed so that the user will heat the food on the stove and then put the pot into the wonder-box in order to finish the cooking process. 10 Save80 stoves and wonder-boxes were distributed to chosen families in Aw-barre refugee camp through a pilot project. According to Aw-barre staff, the project was terminated for several reasons. Although the system is very effective, it is not adapted to the cooking culture and habits of the Somali refugees. Some of the reasons mentioned by the refugees for why they did not use the stove was that the input hole for firewood was too small, the stove produced too much smoke (the Somalis prefer to cook inside), the stove is too tall (the Somalis prefer to sit on the ground or on a short stool) and they couldn't use their regular pots and pans. However, UNHCR officials expressed discontent on the number of pilot studies (and other kinds of research) conducted that did not evolve into a permanent solution. "Research projects and pilot studies are great, and we highly encourage them, but we would like more of this to turn into something useful for us", one UNHCR official stated.

### 2.5 Income gathering and livelihood

Refugees come from all parts of society and most of them have capacities that go unused. Refugees were observed who had created their own livelihoods, as well as livelihood programmes set in motion by UNHCR or NGOs. Some owned small shops, others had animals or produced vegetables and one man sold electricity from his own generator. Some refugees also built stoves from old USaid tin cans. Enabling refugees to create a livelihood is also beneficiary for the local community as a whole. Increasing the range of products and enhancing the purchasing power of the refugees will stimulate the local market, thus enabling a more healthy economy. In the Aw-barre and Sheder refugee camps the refugees, in addition to some food-aid, receive 100 birr (approx. 5.2 USD) per family member per month in order to purchase the goods they need. The refugees met in these camps seemed satisfied with this system, as it enabled them to make a choice as to what food and other items they would purchase. This system can further stimulate the local market, where non-refugees from the local community, as well as the refugees, will come and sell their crops and goods.

## 2.6 Communication

Translators were assisting the design students from Gaia, ARRA and UNHCR that were all familiar to the refugees. This seemed to confuse the refugees as to what was the role of the students. This might have affected their answers, as the refugees may have answered in the way they assumed would benefit them the most. Also, the translators were mostly men, and an impression was that some of the women were quite uncomfortable having not only us, but also them in their homes and kitchen. In addition the translators were not trained interpreters and should have been better briefed by us beforehand on how to act towards the refugees in order to not compromise the findings. It seemed they did not interpret every word of the refugees' responses, but rather gave us a summary of what was said. Occasionally two interpreters were needed as Somalis and Ethiopians speak different languages. One solution to bridge a communication gap can be to use participatory approaches. A participatory design session was attempted with one of the refugee women. The value of the results can be discussed, but it was apparent that other skills are needed in order to conduct participatory design with participants from an unfamiliar culture especially when interpretation is needed. by trying to get the refugee woman to help us identify key aspects of her cooking habits as well as how she wanted a stove to perform through drawing on a piece of paper. The woman was reluctant to engage in the process and was not particularly interested in drawing. In addition, trying to engage someone who is not easily engaged when not speaking directly to her, but through an interpreter, was another challenge. Not all people are used to state their opinion. In a context where the end-user has little power over their own livelihood and way of living a general belief that their contribution will not be taken into consideration was apparent.

## 2.7 Ethics and safety

During the field study in Kebribeyah the impression became that it was only the permission of ARRA/UNHCR office and field staff that was needed in order to conduct research that affected the refugees. In a situation where the refugees have lost much of the jurisdiction over their own daily life and future, further preventing autonomy may create a situation where they are viewed and treated like objects rather than subjects. The students often felt that they were put in an ethical dilemma, which they did not feel they had appropriate tools to handle. Instead they relied on what they call common sense and sensitivity and were questioning how they should define it as appropriate behaviour or not. The last issue that requires attention in the case of designing for humanitarian interventions is the question of safety for the students involved and to balance this against the need for contextually fitted design. Most refugee camps are located in border areas with variable security levels and student projects should carefully consider this aspect of humanitarian design projects. The area this student group travelled to was at the time being considered as stable, but the design group had to take precautions in relation to how to travel, where not to travel and how to avoid health risks. It was considered as key to the students' safety that an agreement had been made with the UNHCR and the Gaia stove program in order to travel safely and to understand the context regarding safety.

# 8 FINAL REMARKS

Even though there are similarities designing for the humanitarian market and the conventional consumer market in development regions, one significant difference that affects the design process is that in the humanitarian market the end-user is not the customer. Not having defined and understood the correlations and differences between what the end-user needs and what the customer wishes to invest in may lead to contextually inappropriate solutions, poor technical performance or products not reaching the end-user. The students have learned that within the humanitarian market there is a multitude of parameters to take into consideration; meaning 'traditional' design methodology might not be sufficient or applicable and that the designer will have to adapt to and understand multiple agendas and power relations relevant to the performance and acceptance of a design. The design might also have to be flexible in its form due to the rapidly changing external factors involved in the humanitarian market. While observing an increase of design methodologies merging for design for development, design for the humanitarian market lags behind.

Based on the discussed observations, it is recommendable that humanitarian designers pay attention to:

1. Geographic context: climate, draught, resource prospects
2. Available materials and human resources

3. Can the design be repaired and maintained locally with limited infrastructure and without supply of extra parts?
4. The existing market structure and value chains
5. Stakeholder relationships, connections and agendas: Who can be useful collaboration partners?
6. The needs of the humanitarian customer wants (the purchaser, in this case not the end-user)and what influences the choice of the humanitarian customer
7. Remember that first-hand information is always better: For the humanitarian customer a product is desirable if it is necessary, functional and relatively cheap. These are rational criteria for choosing the designs they consider to be most appropriate. For the refugees on the other hand, there are additional criteria for when a product is desirable, such as appearance or other preferences that we would not have had insight into unless we had travelled to the field and gained first-hand knowledge.
8. Consider business potential: What capabilities exist within the solution and the context? Is creation of livelihoods a possibility?
9. (How) can you create a sustainable design within this framework? Analyze the life cycle of the design

More case studies are needed that can lead to advice on practical approaches for designers aiming for this market.


## ACKNOWLEDGEMENTS

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# COLLABORATIVE INNOVATION: A STUDY OF CREATIVE TEAMWORK IN OFFSHORE INDUSTRY AND IN DESIGN EDUCATION

**Nenad PAVEL**[1] **and Arild BERG**[1,2]
[1]Oslo and Akershus University College of Applied Sciences
[2]Alvar Aalto University, Helsinki

**ABSTRACT**
Entrepreneurship is identified as a key activity to creating value to society as well as the successful adaption of the products and services to users' lives. This is why entrepreneurship as concept is finding its way to the curriculum in higher education. To study how entrepreneurship is implemented through problem-based learning practice two case studies were conducted. The first case was from professional design practice including observation and cooperation process mapping in an offshore project. The key aspect of this project was commercialization of subsea seismic sensor technology. The second case was an example from product design education course module including observations of teamwork meeting, team member interviews and archival studies. The key aspect of this project was commercialization of a service. The concept of collaborative innovation, strategic entrepreneurship and problem framing was used to analyze and compare these two cases in order to study how entrepreneurship can be taught through problem-based learning and thus to identify relevant learning outcomes for project management in design education. While the first case study demonstrated how a company was establishing collaborative network to exchange expertise, the second case study showed how students were involved in idea and opportunity exploration process.

Keywords: *Strategic Entrepreneurship, Problem Framing, Opportunity and Advantage seeking*

## 1 INTRODUCTION: ENTREPRENEURSHIP IN EDUCATION

Entrepreneurship is important for national economies as it contributes to job creation, productivity and economic growth. [1] Innovation and entrepreneurship are rapidly finding the way into higher education curriculum across the fields and subjects. University college education that is practical and implemental is particularly expected to provide better understanding to their students of how innovation happens and how it's being commercialized [2]. In response to this trend, the product design curriculum at a university college has been adjusted to incorporate entrepreneurship and direct cooperation with companies. This change is the basis for this case study which addresses the possible effects the role of entrepreneurship might have if included as a study module in a design-oriented bachelor program. One of the subjects on Institute for Product Design is especially dedicated to this goal, incorporating a course plan similar to start- up camp -'gründercamp' being organized by Norwegian organization Young Entrepreneurship -'Ungt entreprenørskap'. The course plan similarly to the start- up, implements cooperation and coordination of a student group. Real problem from a real client and a tight deadline of four weeks to final idea implementation and presentation.

### 1.1 Situated creativity in problem based learning

In this design education setting, students are using theoretical knowledge and skills to solve practical problems where the problems are vague and undefined [3]. Students have to be able to collaborate in order to learn fast, define and solve problems [4] throughout problem -based learning activity. This approach allows students to construct knowledge individually and co-construct through interaction with environment instead of getting knowledge transferred by a teacher. However, this interaction is limit by the participants in the learning process in this case students and teachers. As innovation occurs on many levels in product development, from ideation to execution, the perspective of involving students with external partners can be valuable for both problem –based learning and collaboration skills. Although the value creation is the goal defined in this practice [5], it seems to be unclear what the gain is in this type of collaboration in school setting for both companies and students. There is a need to expand knowledge about this education practice, reflected in a pedagogical model that includes practice in collaborative design work. The research question therefore is: How can problem based learning be enhanced through establishing design network? This question will be discussed in relation to what extent the product designer can be situated in the creative process through a collaboration network.

## 2 METHOD: EMBEDDED CASE STUDY

### 2.1 Case study and participatory methods

Case study was chosen because there was a need to exemplify theory in the field [6] from a realistic professional context [7]. In order to understand how collaboration and innovation are managed in practice a relevant design project from the offshore industry was chosen for the case study. Participatory design approach [8] was used to gather the documentation from offshore field work in order to examine the organizational structure and dynamics of cooperation between participants in the process. Case study contains observation of a student group doing their project to gain direct information about their everyday practice and perspective concerning design process in school setting [9]. This project had a cooperative value, defined goal, but with an open ended result expectation, which was needed for this research in order to examine its opportunity seeking character. Archival studies of their project reports were used to analyze their reflection on accomplished project.

### 2.2 Cross case analysis

In order to study how design collaboration network can give value to problem based learning the concept of strategic entrepreneurship and collaborative innovation [6] are examined. Strategic entrepreneurship refers to firms' pursuit of superior performance via simultaneous opportunity-seeking and advantage-seeking activities. Collaborative innovation is the pursuit of innovations across firm boundaries through the sharing of ideas, knowledge, expertise, and opportunities. The interplay of these two concepts can define the value of external collaboration in higher design education in a strategic sense [10] because it examines how the innovation activities affect collaborative network. The other important aspect of the study is the pedagogical concept of context restructuring and problem framing through reflection in practice [11] that is crucial for knowledge construction in problem based learning and collaborative innovation.

## 3 RESULTS FROM PRACTICE AND DESIGN EDUCATION

### 3.1 A case study of collaborative innovation in subsea technology.

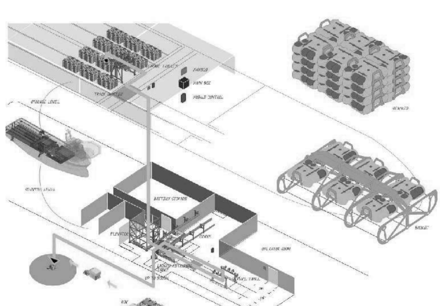

*Figure 1. Seismic sensor technology logistics*

In this case study the design undertaking was to commercialize seismic sensor technology (fig.1) and explore the possibility of higher scale sales. Technology gave a far richer 4D data that included the time aspect that enabled easy oil and gas detection. By compressing seismic sensor unit size and optimizing handling system, the number of sensor units per vessel was doubled and operating time of a sensor unit planting reduced to one minute. Seabed, now SeaBird, is the owner of the technology and a seismic vessel was recruiting possible suppliers through series of pilot projects. These pilot projects were time consuming and on one hand, determined processes but on the other hand, opened arena for practitioners in the engineering team to gain new knowledge.

### 3.2 Strategic innovation: opportunity seeking and advantage seeking

Software and electronics were designed at a separate division in SeaBird that was the core of the new technology. Logistics and design were partly outsourced to a company that suggested including a product designer as a permanent member of the team. A company that was specialized in airport baggage belts for passenger self-service designed the onboard handling system including trolleys and elevators for automatic transport of the seismic sensor units. The system thus was based on engineering skills and knowledge about logistics. The company that specializes in remotely operated vehicle [ROV] navigation executed the subsea sensor unit handling (fig.1). This company was providing the whole subsea navigation service and they were a source of knowledge that enabled the core team to define design demands for the seismic sensor unit and the ROV tool. The sensor unit deployment system and ROV tool that was handling subsea load and placement of the sensor units was fully outsourced to the engineering company that handled high quality mechatronics to sustain active deep-water use. The construction of the sensor unit components were also outsourced to the series of companies. A metal frame and metal vessels were outsourced to a company specializing in metal processes and this knowledge transfer has influenced the frame design and handling procedures. The sensor unit shell was produced by the company specialized in rotational moulding that allowed design of numerous multipurpose features of the sensor unit for both onboard, subsea handling, maintenance and human interfaces. The team leader stated that '*The crucial factor for innovation success was early, initial involvement of suppliers through pilot projects. This allowed the team not only to make strategic partnership decision but also learn new practices they were not familiar with'*. The Seabed team was constituted by two chief operators that were working both on development in the laboratory and offshore operating seismic procedures on the vessel. Others in this team were an engineer, a chief developer engineer and a product- designer that was outsourced from another company. The designers' role was to design systems and product features, but also to facilitate discussions through visualizations, animations and concept generation by exploring supplier's competencies. The product designer was working daily with chief operators on human aspects through participatory design. Daily decisions were made through discussions and operation mock-ups. This understanding enabled the designer to facilitate assembly and operating system procedures through manuals and user interfaces. The product designer was working intensely with an engineering team but also communicating on daily basis with suppliers about solutions and thus organizing relevant discussion topics. In practice it took a lot of testing of the sensor unit handling system. The tests demonstrated that the results were fair but also that the system needed improvement. The commercial goal was achieved when an average sensor unit planting operation took one minute. At that point it was not just technological improvement but provision of a relevant service. The process was generative and the participants were expanding their knowledge as well as making solutions. In this approach both people adjusted to the system and the system were adjusted to people. The design project got Honors Award for Design Excellence at the annual evaluation of Norwegian Design Council. It was also nominated for Best Design in British Design of the Year 2010. The concept was characterized as innovative and benefits were identified to especially contribute to functionality in terms of logistics and timing but also branding. It changed the perception of the clients of the data sales service.

### 3.3 A case study of collaborative innovation in design education.

The goal of the second case study was to exemplify a student project in context of educational setting similar to start -up camp as mentioned in the introduction. In this subject module problem -based learning was set to simulate a design office with young design entrepreneurs providing their services to their first client. Prior to this subject module, students were trained for two weeks in different skills: third year students in dynamic project leadership; second year students in branding, presentation and communication; and the first year students in mock-up building and workshop equipment. The design students were then merged in several groups of up to twelve students across the three years of bachelor program. Each group was organized so that each class could exercise the theoretical knowledge they had gained in previous two weeks. The thought behind this subject module was that students were encouraged to use design creativity to exercise innovative entrepreneurship [12] and to use design as tool for commercializing new technologies with focus on human factors. The pedagogical goal was to facilitate develop self- efficacy, motivation and independency as well as sense for responsibility and value creation [13]. A student group was observed during a 4 weeks period in November and December 2012, and interviewed after the concept generation phase and at the end of the project. They were told that observation and interviews were conducted as part of the subject evaluation.

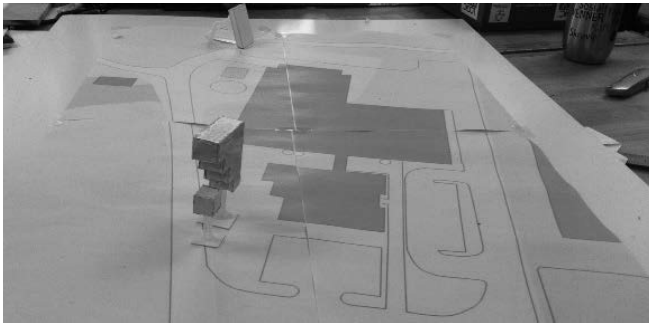

*Figure 2. Akershus Energy information board*

The project was carried out in cooperation with Akershus Energy, a local hydro energy plant company providing house heating. In order to stay competitive the plant has to implement new technologies and widen harvesting capacities to be able to reduce prices. The plant was therefore seeking the opportunity to expose itself to the local community, raise the awareness of its benefits to environment, create goodwill and raise satisfaction among the customers. The students gathered information about the energy plant and concentrated on the building surroundings. They examined what are the values their partner wants to communicate, what it means for the community. They have defined the framework of the project, in terms of system demands where the focus was on information delivery and education in terms of cognitive, sensory and values communication with the user. Students have used concept generation as a main tool to explore the problem, discover and discuss potential new product demands. The results for the concept generation period showed that the first group had not considered any other design aspects than those that were discussed with the client, that the client had pointed out or that they have discovered themselves through concept generation. Students had a weekly review with a client as well as email communication. The leader stated *'We have a tight cooperation with the client and he is providing us relevant information that we need to know'*. After the first round, students were encouraged to get a feedback from previously defined user groups. Conducted interviews with users within their target group influenced their choice of the concept for further development. However, the concepts were not tried by users, but rather further discussed with the client. The final concept was then presented as a 1:3 scaled functional prototype to the client and conclusions were drawn. The students claimed that they were not consulting literature since they had a practical task in a short period to complete, but they stated that they had used methods they already had learned from the previous two weeks training period. The final concept was generated around the idea that the series of attractions for the plant surroundings could provide the vivid experience, learning and motivation for visitors, especially families to come and build more connections with the client through time. The students had focused on creating a '*welcome installation'* for the visitors that would provide information as well as give identity to the area.

## 4 DISCUSSION: COLLABORATIVE INNOVATION IN DESIGN

### 4.1 Commercializing technology

In the first case, the company was already delivering seismic data to the offshore exploitation market when it started the project. The company had a goal to seek for advantage on the market by commercializing its incrementally innovated technology [10]. The goal was to enable streamlining of the data gathering process through mechanization and optimization of complex sensor handling logistics (fig.1). The company has established collaborative network by selecting supplier partners over series of pilot projects for already framed problem. By initiating pilot projects with a number of suppliers the company had chance to examine and decide on knowledge and expertise network needed to solve series of small design problems through collaborative innovation [14].

### 4.2 Creating the information and knowledge network

In the second case, the company has established cooperation network with students in order to explore the means for the company to connect to its customers in an appropriate way. The goal of this cooperation was to explore opportunities and get ideas for potential further collaboration and problem framing. The goal of the project was decided but the problem needed framing and interpretation, as discussed by Schön [15]. Students then needed to create network by reaching the customers and potential suppliers to discuss realization of their ideas. As this was happening on ideation level, they never got to the point of generating final solutions. They also had to spread in smaller groups, gather the necessary knowledge fast and use it to examine potential concepts. As their resources were lesser and spread, they have not developed this network to the level where sufficient knowledge transfer would occur as a creative flow, as promoted by Csikszentmihalyi [16].

### 4.3 Strategic entrepreneurship through collaborative innovation

Both small and large firms face weaknesses while pursuing strategic entrepreneurship [14]. While small companies may have strong skills in opportunity-seeking, their limited knowledge resources and lack of market power prevent their ability to enact the competitive advantages necessary to appropriate value from opportunities the firms choose to pursue. In contrast, large firms are skilled at establishing competitive advantages, but their heavy emphasis on the efficiency of their existing businesses often undermines their ability to explore continuously for additional opportunities. In both of the cases, studied companies are managing the strategic entrepreneurship in their customer offering through establishing networks. In the first case the company has established collaboration and in the second case cooperation.

#### *4.3.1 Creation of knowledge network*

In the first case the company is managing to maintain its core business while being an owner and developer of the new technology through collaborative network. In the second case the core business is maintained while the new income concepts have been fully developed in collaborative network. The smaller partner companies in these two case studies are also managing their strategic entrepreneurship in a less successful fashion. While most of the suppliers in the first case study profit through knowledge transfer experience and developing a new fields for their consultancies for example, from airport baggage belts to offshore equipment, the new found student design consultancy company is struggling with the lack of knowledge and market power to gain competitive advantage [10] from their design skills.

#### *4.3.2 Concept and knowledge exchange without boundaries*

The concept of collaborative innovation emphasizes two aspects: knowledge or expertise and idea or opportunity exchange without boundaries [10]. Opportunity seeking still seems to be a key for small companies where the harm of initial trials and errors are limited by the very size of the company and scope of the project. According to Schön [15] opportunity seeking is explained as a continuously changing problem and context reframing process or idea exploration. This value emerges from discussing and interpreting a design problem. In the two case studies, collaborative network has been used differently. In the first case, the company owning the new technology has the framed problem and is using collaborative network for the knowledge and expertise exchange in order to realize the market potential. In the other case the company with the defined goal but undefined problem is using collaborative network to explore ideas and opportunities.

## 5 CONCLUSION: IMPLICATION FOR DESIGN EDUCATION

Problem-based learning is according to Bound [3] a co-construction of knowledge in interaction with environment where collaborative networks stimulate students to operate in idea and opportunity exploration area. Although this is of value for students with realistic feedback from the client, the network and collaboration setting is not sufficient for expertise and knowledge exchange. As innovations are happening on many levels [17], students might be missing on learning how to manage expertise exchange in a project setting. The attempt to put them in the entrepreneurial situation did not fully reflect the real life outside the school.

### 5.1 Learning outcomes in dynamic project management

The results shown indicate that it is difficult and not likely for collaborative innovation to occur in education where project management is situated in various settings, as proposed for learning through reflective practice [15]. According to educational research strategies learning outcomes should be identified [18]. These relate to knowledge, skills and general competence. Relevant issues identified in the study were within the knowledge domain that students should be able to commercialize incrementally innovated technology. Further students should be able to exchange concepts and knowledge without boundaries. Within the skill domain, students should be able to create and use information and knowledge networks through collaboration not only cooperation. As a general competence, students should be able to manage strategic entrepreneurship through collaborative innovation. This is relevant in entrepreneurship education to be attuned to professional practice. Design educations can contribute to this by enabling interdisciplinary environments for problem based learning and teaching students to use time on development of necessary networks for knowledge sharing.

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# COMPUTER AIDED COST ESTIMATING

**Huub EHLHARDT**
Faculty of Engineering Technology, Section of Product Design, University of Twente and Philips Innovation Services, Eindhoven, The Netherlands

**ABSTRACT**
Digitalization provides us with increasingly sophisticated tools, such as 3D CAD and ERP, that have become drivers of innovation in many industries. Traditionally, estimating product cost requires both craftsmanship as well as elaborative calculations. Product cost estimating practices are currently advancing with new digital approaches that, in this paper, are referred to as Computer Aided Cost Estimating (CACE) tools. CACE skill will give new engineers entering the manufacturing industry an edge, especially those in positions in which the cost of goods is an important aspect. This paper describes a new family of engineering tools referred to as CACE, elaborates on the use of cost estimating through the product lifecycle, and relates this to the educational context. The paper contemplates how CACE software might continue to develop and provides suggestions on how best to incorporate the development of CACE skills into engineering curricula.

*Keywords: Cost engineering, cost estimation, Computer Aided Design, product lifecycle management, teaching software*

## 1 INTRODUCTION

Since the advent of the personal computer a huge number of software applications have been introduced that have innovated the way we work. In the case of engineering, Computer Aided Design (CAD) has been developed as a core application since the end of the 1980s. CAD made the drawing board obsolete. More importantly, CAD made a host of new applications possible that further innovated engineering. Examples are Finite Elements Analysis (FEA), Product Lifecycle Management (PLM) and Computer Aided Manufacturing (CAM). The FEA software family provides applications that calculate and or optimize issues in domains such as strength and stiffness, plastic injection moulding or magnetic fields. PLM software is used to manage data throughout the product lifecycle like drawing numbers, Bill of Materials and engineering changes. The CAM software family enables applications such as Computer Numerical Controlled (CNC) milling and Rapid Prototyping. The wide variety of software used, also referred to as application landscape, has become indispensable for the operation of modern manufacturing industry and is set to continue driving change.

One of the new software applications for engineering that is currently gaining ground is related to the calculation of cost associated with the production of goods, also referred to as product cost estimation (PCE). In discrete manufacturing industries, cost engineers are using home-grown templates based on Microsoft (MS) Excel and or Access to calculate the cost of manufactured goods. Various consulting firms have developed slick versions of such templates, often linked to extensive databases with machine and labour rates. Various software vendors have developed more advanced PCE software. No generic name for this type of software has been adopted yet, although its use is currently gaining ground in discrete manufacturing industries. This paper refers to this family of applications as Computer Aided Cost Engineering or Computer Aided Cost Estimating (CACE) software. Various approaches to CACE are available in the market. There are currently no set standards for CACE software, either in cost calculation approach, user-interface or features, or in interfaces with other applications (CAD, PLM, ERP). The use of CACE software is not yet common practice throughout the manufacturing industry. There are many vendors from different backgrounds. It would appear that a dominant design for CACE software has not yet been established. Given the expected further digitalization of tools, it is likely that CACE will continue to develop and become part of the application landscape catering for functions involved in the development and production of goods (see also Figure 1). This paper explores this new family of CACE software and discusses how it can be embedded in engineering curricula.

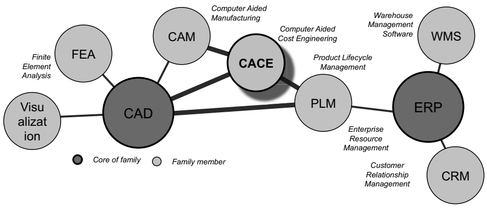


*Figure 1. CACE in a landscape of applications used by the manufacturing industry*

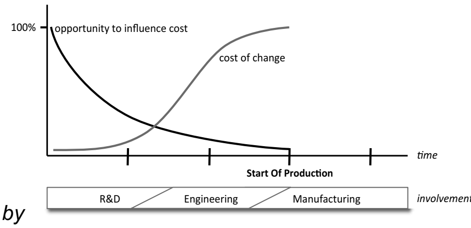


*Figure 2. Costing through the Product Life Cycle*

## 2 ESTIMATING COST

There is no single right way of estimating cost. Depending on the position in the product lifecycle or the value chain, PCE has different objectives. Different perspectives and industry characteristics have led to numerous different approaches to PCE.

### 2.1 Use of PCE throughout the product lifecycle

Diagrams like Figure 2 are often used to show how 'the opportunity to influence' cost rapidly decreases as development progresses. In the early stages of research & development (R&D), the accuracy of a cost estimate is not that high as designs are not yet fixed and many uncertainties remain. The function of PCE here is mainly to identify cost drivers in order to support decisions on architecture, materials and or manufacturing technologies. Once a product specification has been set, the opportunity to influence cost rapidly decreases. For that reason it is relevant to understand the cost structure early on in development, as the influence on cost is highest here, and cost invoked by change is lowest.

During the engineering phases, the product design is further detailed en route to a final stage where the design is frozen and drawings are further detailed to enable the ordering of tooling required for production. Once tooling starts to be ordered, the cost of changing a design increases dramatically. At the end of this phase, the opportunity to influence the cost via the design is reduced to zero. Cost estimates are used in this phase to support decision-making between alternative solutions for constructive details and therefore a higher level of accuracy is required than in R&D. During the engineering phase, 'make-or-buy' decisions are made. Many so-called head-tail companies outsource the production of components and/or assemblies to specialized suppliers.

Towards Start of Production (SOP) the required accuracy of PCE is highest. Outsourcing production to suppliers requires purchasers who negotiate on the cost of manufactured goods. In order to negotiate meaningfully, a purchaser needs to know what a product should cost. For this purpose highly accurate cost estimates are required. These are commonly provided by cost engineers. After SOP the opportunity to influence cost is low. Commercial negotiation or moving production to regions with lower labour costs is the most commonly-used method. Alternatively, the product can be redesigned, which effectively means a new version of the product that has to go through a development cycle all over again.

On the side of the supplier, the required accuracy of PCE is also high. After all, if the goods they manufacture are sold for less than the cost incurred when manufacturing them, a loss-making situation will arise. Suppliers therefore employ so-called estimators to calculate the cost of manufacturing goods in order to prepare quotes.

### 2.2 Methods and techniques for Product Cost Estimation

A large number of methods can be used to estimate the cost of products. An extensive overview of PCE techniques and methodologies is provided in [1]. This article describes no fewer than 12 different PCE techniques and classifies these, according to their approach, as quantitative or qualitative. The qualitative techniques are primarily based on comparisons of similarities between new and existing products. The quantitative techniques are based on a detailed analysis of products and manufacturing processes used. Each of the techniques has its own key advantages as well as limitations. A prominent quantitative technique which is discussed in more detail in this paper is Activity Based Costing

(ABC). The ABC methodology focuses on cost allocation and helps to segregate fixed costs, variable costs and overhead costs. The article does not elaborate on cost estimating software. However, it describes a group of Decision Support Systems that comprise rule based, fuzzy logic and expert systems which it classifies under the qualitative techniques.

The use of software to support PCE is discussed in an article by Micro Estimating Systems [2]. Three strategies are described, namely standards-based, engineering-based and intelligent emulation. The standards-based strategy uses a library of standards for particular manufacturing operations and assigns these to estimate cost. The engineering-based strategies use formulas to calculate the amount of time it takes to execute a particular manufacturing operation, also referred to as cycle time. The standards-based and engineering-based strategies require expert knowledge in the estimator to decide what type of machine and settings need to be used for particular operations. The article underlines the importance of using the right assumptions to derive the cycle time for particular manufacturing operations, as it is one of the key drivers of manufacturing cost. Obviously, the level of expertise of the estimator has a major influence on the accuracy of the cost estimate produced. The engineering-based strategy would be classified in [1] as an ABC method. The third method, intelligent emulation, applies algorithms to emulate manufacturing process to derive accurate estimates of cycle times. Examples of these algorithms are also found in CAM software used to program CNC machines or FEM software like Moldflow used to emulate injection moulding.

## 3 CACE SOFTWARE

With the advance of computing in the manufacturing industry software used to estimate product cost also became available. Academics have described [3] how they developed a system this paper refers to as CACE software. Vendors are now offering various types of CACE software and applying different levels of automation and approaches influenced by their background. No classification has been developed so far for the different approaches used in CACE software. Several vendors adhere to the ABC method. Others have developed software that reads 3D CAD files and automates a large part of the PCE process. As [1] and [2] do not provide an unambiguous classification for this automated type, they are referred to here as automated cost estimation (ACE).

The ABC types may be based on templates in MS Excel or Access as also used in dedicated environments. In general the ABC-type programs are very flexible in the type of manufacturing operations and complexity of products they can provide PCE for. The software operator can add machine types and assign investment levels as well as figures for the consumption of energy, consumables, required space and maintenance. The software automatically derives a tariff for use of the particular equipment per unit of time. The operator configures a calculation by selecting the type and amount of material used, the equipment to be used and then provides all the process parameters (such as cycle time, batch-volumes, set-up time, amount of operators, scrap level etc.) as input as well as levels of overhead associated with a particular type of manufacturer. This enables the costs to be modelled of virtually any (manufacturing) process and is as accurate as the input provided. In general, the ABC approach is known to be time-consuming and requires a significant level of expertise to use.

The ACE types that have so far focused on PCE for metals and plastics commonly use 3D CAD information as input. In these programs, the user has to select a small set of variables, namely material type, type of manufacturing operation and annual or batch volumes. Based on the settings and the information provided in the CAD file, ACE types derive an optimal manufacturing path and process times by emulation. Various approaches to ACE-type systems are available. Some ACE types can provide information on the cost of features (such as a particular radius) and so help to identify cost drivers and or suggest improvements to design engineers that reduce costs. The costing of electronics can be approached using ABC-type costing tools. Cost of Printed Circuit Boards (PCBs) is driven by the cost of components used. Commonly list prices are used for such components, which require up-to-date references (price erosion, obsolescence) and depend heavily on purchasing volumes.

Both ABC and ACE types provide tools to present or visualize results as well as tools to analyse the effect of different manufacturing strategies in relation to production volumes.

Although PCE appears to become simple with the availability of ACE-type software, it should be noted that, as with any type of software used for analytical purposes, the quality of information used as input defines the quality of the output. This observation is generally applicable in computer sciences and is often rephrased as ‘garbage in, garbage out’ (GIGO). Practically this means that an experienced user continues to be required for the successful operation of CACE software, both to incorporate

meaningful data into the software, as well as to interpret results in order to filter useless output. In general, ABC-type costing is more sensitive to GIGO than the ACE types, as ABC types require more (manual) data input.
The main CACE applications available are (by vendor); aPriori (aPriori), Costimator (MTI Systems), Concurrent Costing (Boothroyd Dewhurst), Micro (Micro Estimating Systems), Perfect Costing (Siemens), SEER (Galorath) and SolidWorks Costing (Dassault). Four of these are briefly described below.

### 3.1 Example 1; Perfect Costing

Formerly known as Perfect ProCalc, the Perfect Costing software was brought to the market by Tsetinis, a consulting firm founded in 2000 that is primarily active in the German automotive industry. In 2012 Siemens PLM Software acquired Perfect ProCalc and integrated the costing software into their engineering software portfolio. As part of the integration, the user interface look and feel was adapted to Teamcentre, their PLM solution. Perfect Costing uses the ABC approach to analyse costs and is featured with an extensive database close to 300 production regions and over 3000 types of equipment for which it provides labour and machines rates. This database allows for swift evaluation of the cost effects of moving production from regions with high labour costs to those with lower ones. Perfect Costing provides some tools to calculate cycle time and allows the inclusion of documentation (e.g. 2D drawings, photographs and excel calculations) in calculations. Perfect Costing software is currently known to be used at one engineering school in Germany. Siemens is preparing an academic bundle.

### 3.2 Example 2; DFM Concurrent Costing

Boothroyd Dewhurst Inc., that has specialized in Design For Manufacturing and Assembly (DFMA) tools and services since 1983, is the vendor of the PCE tool DFM Concurrent Costing. It is a hybrid tool in the sense that it can produce cost estimates starting with importing 3D CAD data from which it derives calculation input, as well as by defining manufacturing operations completely via manual input. Concurrent Costing includes a library with a wide range of equipment for machining, moulding, electric and assembly operations. The software assumes a single region (USA) where manufacturing operations take place, although rates can be altered into figures common for other regions. Concurrent Costing is complementary to a Design For Assembly (DFA) tool by the same vendor. It is unknown if the software is currently being used at engineering schools.

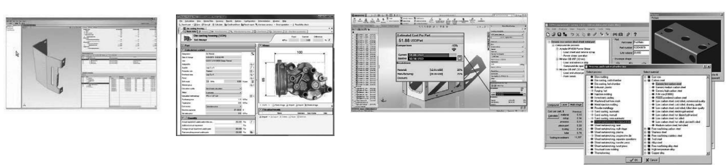

*Figure 3. Screen shots of (left to right) aPriori, Perfect ProCalc, SolidWorks Costing, Concurrent Costing*

### 3.3 Example 3; aPriori

aPriori, marketed by a company of the same name, requires 3D CAD data as input to start a cost estimate and is an ACE-type program. The focus of aPriori is on the costing of metals and plastics, including all kinds of surface treatments that are commonly used for these materials. aPriori does not allow automatic cost estimating for electrical parts like printed circuit board assemblies (PCBAs) as these are not described with 3D CAD. It uses so-called virtual production environments (VPEs) that cover labour, square meter cost and energy prices associated with the particular production location as well as typical overhead structures assigned to suppliers used. Standard aPriori offers a library of less than 10 VPEs, which means that it needs to be supplemented for all cases in which complex supply bases are used, covering multiple regions and suppliers to which different overhead cost structures are assigned. In an educational setting, aPriori software can be used in conjunction with training in CAD and (the design of) manufacturing subjects that support the development of an understanding of cost drivers in designs. aPriori is currently used in a few USA and UK based engineering courses. An e-book designed to use aPriori in design for manufacturing classes is currently being written.

### 3.4 Example 4; SolidWorks Costing

Dassault is the first major CAD vendor to integrate a costing solution as a module into its 3D CAD software. SolidWorks Costing allows design engineers to continuously check the design against cost. The automated cost estimate is updated as soon as a design is altered. The costing module only provides a cost estimate for sheet metal and machined parts and that significantly limits it use. Since 2012 the costing module has been part of the SolidWorks Education - and Student Edition. According to Dassault, over 28,000 licenses have been sold to schools, providing it with significant exposure to engineering students.

### 3.5 CACE outlook

CACE software is a family with no dominant design so far. As the manufacturing industry is a very cost competitive business, cost estimates will remain an important element, from R&D through to manufacturing. Consequently, the expectation is that the use of CACE will increase wherever it contributes to business competitiveness by making the PCE process more efficient and accurate. Ultimately the use of CACE will increase cost transparency and thereby influence the relations in supply chains.

Other types of software, like office and engineering applications, have clearly been evolving towards higher levels of sophistication and interoperability. Often, separate applications are bundled in software suits (like Microsoft Office), differentiated by level of complexity or sophistication (home versus business editions). Similar, CACE can be expected to evolve in level of sophistication (ease of use, accuracy, amount of processes covered) and with regard to integration into and or interfacing with other types of (engineering) software (e.g. CAD, PLM or ERP).

## 4 CACE IN AN EDUCATIONAL CONTEXT

Offering CACE to engineering students will help them develop an understanding of cost in designs produced. As such, it makes sense to contemplate embedding such tools in engineering courses. ACE-type costing software will be easier to use by students than the ABC types.

The manufacturing industry requires graduates to be familiar with modern engineering tools. CAD skills are obviously relevant for those entering design-engineering positions. Various authors [4], [5] wrote in this context on the use of other engineering applications. It became clear [6] that teaching complex high-end 3D CAD systems requires lengthy training. At the University of Twente, a course in Solid Works as part of a Bachelor's degree is assigned 4.5 European Credits (roughly 125 study hours). Many educational institutes only offer courses in mid-end applications of a lower complexity which are easier to teach. Once familiar with the user interface and conventions of a low or mid-end version of a CAD application, it is relatively easy to extend skills towards the more complex high-end versions. Educational institutes should therefore focus on making students familiar with the principles of engineering software tools using low or mid-end versions, rather than getting bogged down in teaching proficiency skills for overly complex high-end software.

Training in engineering software, such as CAD, using a traditional classroom method, requires expensive staff [6]. Online video-based training is an educational innovation currently gaining ground as a low-cost alternative to classroom teaching for students as well professionals. It is flexible in use, not bound by time or location and easily scalable for a larger audience. Teaching engineering applications using online video-based training offers the opportunity to increase the efficacy of educational processes. CAD vendors already provide online video-based training for their software. The expectation is that online video-based training will become the standard for CACE as well as it provides an efficient and flexible route to acquiring skills.

The available CACE software is maturing all the time. CAD software currently available is offered to different user segments. This might provide clues as to how CACE software can develop. Low complexity freeware versions with simple features are available for users with limited financial resources and/or minimal requirements. Demanding users can opt for expensive high-end solutions that integrate all types of applications. PTC offers a freeware CAD solution that enables the drawing of up to 60 parts in one drawing. Paid solutions by the same vendor offer more functionality but can cost more than ten thousand euros per user. Table 1 provides an overview of CAD applications arranged by complexity and cost level (or user segment).

In the case of CACE, no software portfolio strategies for use by CAD vendors have yet been developed. However, freeware versions of CACE software are already available via the web portals of

Additive Manufacturing suppliers. A quote can be generated simply by uploading a 3D CAD file and selecting a particular process, material and finishing. Hence, it is an example of automated cost estimation.

*Table 1. 3D CAD applications arranged according to complexity and or typical cost level*

| Freeware (€ 0) | Mid-end (up to € 5,000) | High-end (€ 10,0000 and more) |
|---|---|---|
| PTC Creo Elements/Direct Modeling Express (PTC), FreeCAD (open source), OpenSCAD (open source) | Crea (PTC), SolidEdge (Siemens), SolidWorks (Dassault), Inventor (Autodesk) | Creo Parametric (PTC), NX (Siemens), CATIA (Dassault) |

If CACE vendors choose to adhere to a similar strategy to CAD vendors, differentiation in their software could enable a range of users to be catered for. The availability of easy to use low or mid-end versions will allow students and professionals to acquire the skills needed to operate the software without going through a lengthy training process. This will undoubtedly stimulate the adoption of CACE software. Obviously, as far as engineering students are concerned, familiarity with the approach and user interface of simple versions of CACE software may prove a valuable skill on the labor market. Once they leave educational institutions, such familiarity with modern engineering software will guide new engineers into positions in which they can contribute to the further modernization of engineering professions.

## 5 CONCLUSION AND OUTLOOK

CACE is a new family of software used to produce product cost estimates. Embedding CACE in engineering curricula provides students with tools to analyze cost drivers. As such it increases the insight into the relationship between a design and the costs required to manufacture it.

CACE software will increase the speed and accuracy of PCE. As such the expectation is that its use will increase throughout the manufacturing industry. No dominant design or approach for CACE has yet been set. Vendors of CACE have not yet developed variants for different types of users.

Cost estimating continues to be a crucial element in development processes as well in outsourcing. Outsourcing and supplying manufacturers alike will need employees with the digital skills required to operate their modern cost estimating tools. They expect students leaving engineering schools to possess these skills. Consequently, exposing engineering students to CACE software will provide them with valuable skills and help them succeed in the labour market.

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## Chapter 8

# COLLABORATION

# DESIGNING HOME DECOR PRODUCTS FOR UMBRA, WITHIN THE INTERNATIONAL COLLABORATION FORMAT AS AN ACADEMIC EXPERIENCE FOR UNDERGRADUATE STUDENTS

**Alejandra María VELÁSQUEZ POSADA and Luis Fernando PATIÑO SANTA**
Universidad EAFIT, Medellín, Colombia

**ABSTRACT**
Product Design Engineering at Universidad EAFIT offers a special undergraduate course that allows students to have their curriculum in a flexible way. The main goal is to design home decor products for a world leading company: Umbra. This paper presents a case description of a university-industry collaboration (taking into account previews experiences with other local industries) in which outlines the course's methodology based on Umbra's design contest: to explore fresh and original designs, within the international format *collaborations.umbra.com*. It describes the company's briefing, the design process and the feedback from the company. One of the biggest motivations is that students have the opportunity to design for an international company and have the possibility that their products could be chosen to be produce by Umbra. Among the skills students develop are the ability to read the company's language to understand its brand identity, as well as to increase the application of design tools such as mood boards [1], emotional design [2], the use of semantic adjectives [3] and the use of the formal referent as an inspiring element. The new product must fulfil three requirements: original, practical and keep brand identity, in order to fit Umbra's brief. The most relevant aspect of the course is the professional training students receive in refining the product's form and aesthetics -to adjust the design to the consumer preferences- and how the methodology course enhances student skills, such as creativity and sensibility, in order to get prepare for their out coming mandatory industrial semester.

*Keywords: University-industry collaboration, design education, innovation and product design*

## 1 INTRODUCTION

In the current economic context, the ability to innovate represents a crucial element in strategic competitiveness. Design makes a significant contribution to this process: not only functional improvements, but also formal freshness can be introduced; the product can also be filled with new value and meaning [4]. Some companies search for fresh ideas in undergraduate students, because they are capable to design with accurate methodologies and propose new ideas for the market, proving that these products are innovative and reflect the company's brand.

This paper describes an academic experience between Canadian company Umbra and Universidad EAFIT. At the beginning of 2013, TUGO (Colombia's franchise for Umbra) approached Universidad EAFIT searching for students who might be interested in a design contest within the international format *collaborations.umbra.com.* Around 15 students participated and there was a finalist (Simon Guerra) who won the first place with his product, an organizer for glasses. The owner of Umbra, Paul Rowan, gave a lecture to undergraduate students on *"10 out of 1000 risks I took for innovating at Umbra".* After this experience, our Engineering faculty saw an opportunity to create a "Special Project" course for the second semester of 2013. In this course, students would design home decor products for Umbra. Twelve students with excellent drawing skills as well as an interest in product semantics were selected along with their portfolios. Sourcing projects from industry facilitates access to real-world problems, skill development and project management experience, and has become an increasingly popular feature of design engineering programs [5].

Section 2 of this paper describes the course's methodology of this collaborative project and shows how each stage contributes to the development of an Umbra product design. Section 3 shows how boards are the main tools for designing products according to brand identity, in order to increase student skills related to formal language. Results are presented and discussed in Section 4, while Section 5 presents the paper's conclusions.

## 2 COURSE METHODOLOGY

By modifying the format of Umbra's contest –expanding it from 5 to 16 weeks in order to fit the academic semester of our undergraduate students– the course's methodology is structured in 6 stages: research, inspiration, ideation, embodiment design, detail design and final presentation. Figure 1 shows the stages in ensuring a complete product design process.

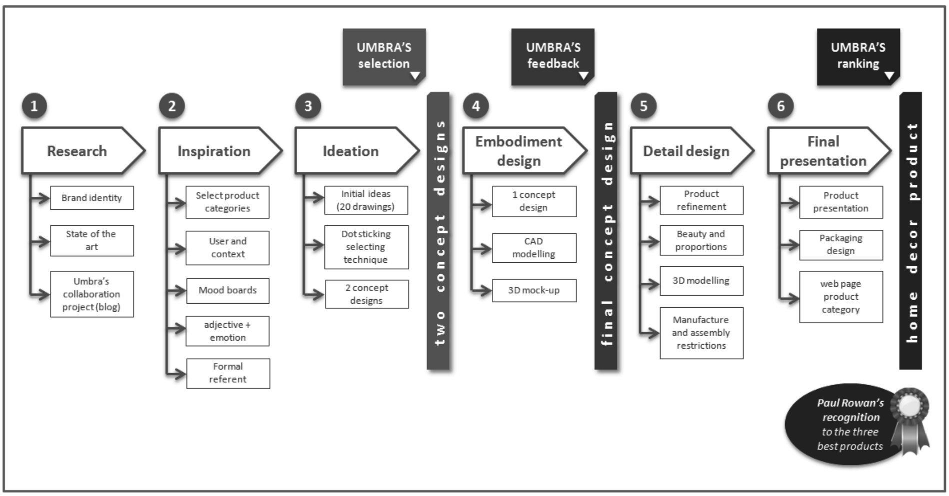


*Figure 1. Design process of home decor products for Umbra, within the international collaboration format as an academic experience*

The stages of the design process are:

- Stage 1: Research. The first weeks of the course are devoted to comprehending Umbra's brand identity and its philosophy. Students have to make a state of the art of similar companies that design home decor products.
- Stage 2: Inspiration. Students have to select a product category of their preference and, by choosing the context and user for that specific product, the inspiration stage starts. By making the mood boards, they also choose adjectives and emotions in order to have an inspiring element (a formal referent such as a tree, a flower, or a geometric figure).
- Stage 3: Ideation. Students brainstorm initial drawings by using the inspiring element to design their new product. Then, they must choose two concepts to develop them in greater detail. By using the dot sticking technique [6] and taking into account Umbra's feedback, students choose their best concept.
- Stage 4: Embodiment design. All the product parts are conceived in order to achieve a final concept design. After this activity, students show their products again to Umbra's design team, so they can have feedback on the final concept.
- Stage 5: Detail design. The detail design stage is for product refinement. Special emphases are placed on the balance, beauty and proportion of the product shape. In this stage, students build a 3D model, taking into account manufacturing and assembly considerations.
- Stage 6: Final presentation. The final stage includes the packaging design, as well as the placing of the product in Umbra's web page (in the appropriate product category). Each student prepares a final presentation to send to Umbra for their final ranking.

The main goal of this six-stage methodology is to guide students in the right way to finding solutions that follow Umbra's brief and their product categories. Umbra's participation helps students by improving their skills in every stage.

In terms of methodology, two types of feedback are given. The feedback from the teacher's course is related to the design methodology (to accomplish every stage presented in Figure 1). On the other hand, the feedback from Umbra's design team is more linked to the product itself (how the design fits into the product category, how the product form matches Umbra´s brand identity, how the idea is original, and finally if the design has a commercial possibility in the market). Nine, out of eleven products, were coinciding opinions in terms of product form by gathering fresh and original design. During the course there were several group sessions to discuss the ideas with TUGO (Colombia's franchise for Umbra) participation. Renders were sent by e-mail, so experts from Umbra's design team can discussed them regarding functional aspects, indicative features of the product, benchmarking, use of materials, original concepts, playful ideas, simple and modern products. They send written feedback through e-mail, at three moments in the semester, so each student can redefine their design.

## 3 DESIGN TOOLS: TEACHING STRATEGY

The collaborative projects that Umbra has with some universities include the Art Centre, The George Brown College, and Shenzen University. They also have an ongoing partnership with the Pratt Institute that is now entering its ninth year. The models vary by school; some will email concepts for feedback, others use the collaborations blog, while, in other cases, Paul Rowan conducts live critiques through Skype or in person.

In this specific collaborative project with Universidad EAFIT, student's concepts are emailed for feedback. The starting point of the project is to understand Umbra's design parameters for home decor products. Figure 2 shows an example of Umbra's design collaboration brief.

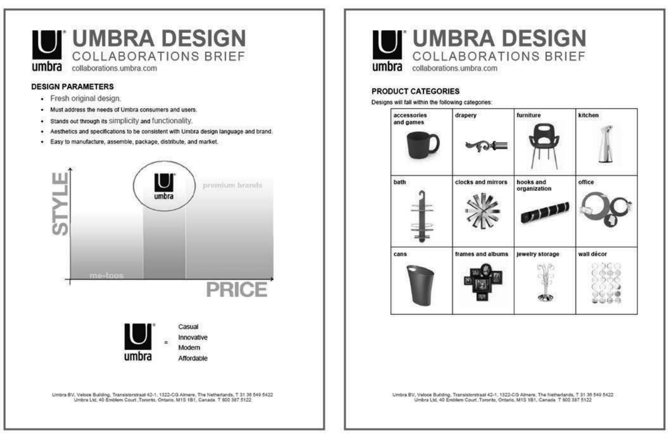


*Figure 2. Umbra's design brief*

During stages 2 and 3 (inspiration and ideation), it is very important that students make three mood boards: the user and lifestyle board, the emotional board and the product board. All of them have one purpose: to achieve a correct product styling according to Umbra's brand identity. As Umbra says: *"The aesthetics and specifications have to be consistent with Umbra's design language"*. Figure 3 shows these three boards.

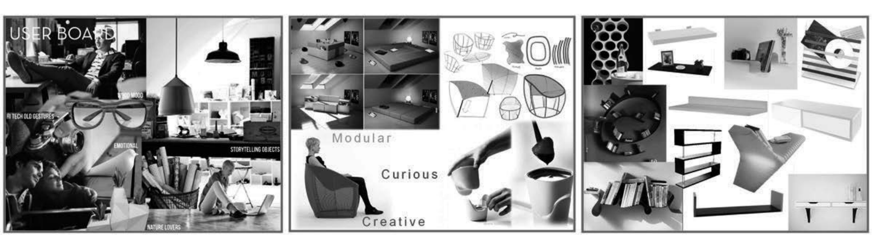


*Figure 3. User and lifestyle board, Emotional board and Product board, as a teaching strategy*

- Board # 1 - User and lifestyle board: This board allows the student to visualize the product user and also his/her lifestyle, atmosphere and environment, the products he/she uses and likes, the way he/she lives, and their favourite colours. *The main goal is to understand if it is consistent with Umbra's market.*
- Board # 2 - Emotional board: The student has to define the emotion that the user will feel with the new product. It is very much like a promise. A maximum of three words should be used. Both emotion and an adjective have to be tangible in the new design. Applied to the product, this is what we call product semantics. *The main goal is to understand if it is consistent with Umbra's language.*
- Board # 3 - Product board: According to the category that each student selects, it is also very important to construct a state of the art and look at similar products to the one the student is designing. *The main goal is to understand if it is consistent with Umbra's brand.*

Design tools are used to improve the methodology, and also to enhance student's performance when designing products in which language must be consistent and coherent with Umbra's brand identity. Figure 4 describes this process.

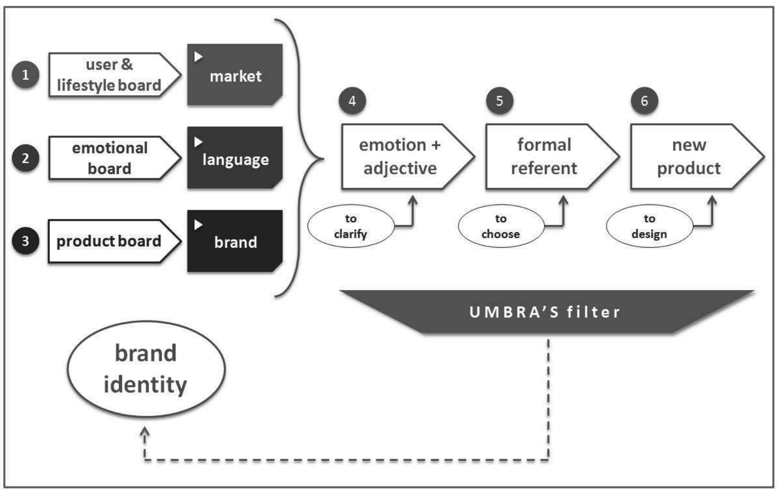


*Figure 4. The three boards as a tool for designing according to Umbra's identity*

After building the three mood boards, the conclusion must be the definition of the emotion and adjective. They give hints for choosing a formal referent: shapes, colours and textures are taken as inspiring elements for designing the new product. This allows fresh and original designs to fulfil Umbra's requirements. The students also use *Trendhal* –a web page built by Manuel Lecuona (Spain)– in their design, using several inspiring elements based on current trends. Figure 5 shows an example of the formal referent.

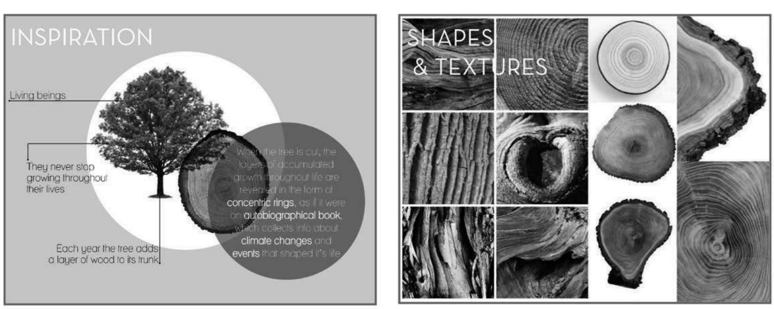


*Figure 5. The tree as a formal referent*

## 4 RESULTS AND DISCUSSION

The results of the "Special Project" course were eleven new home decor products for Umbra. Students made digital presentations and physical models. Pictures of these and the final presentations were sent to Umbra's design team for the final ranking, as shown in Figure 6.

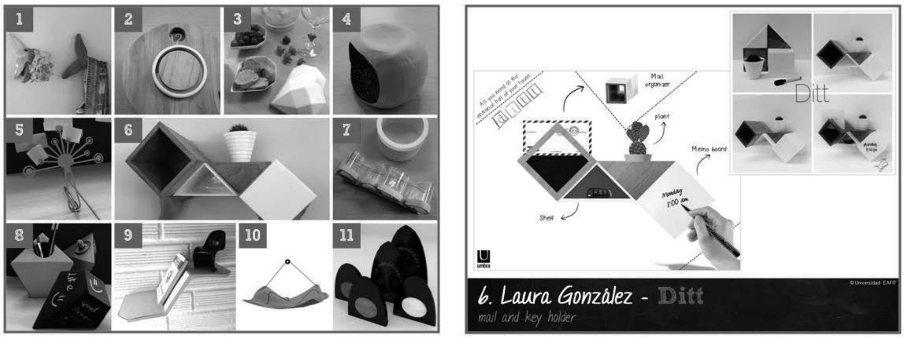


*Figure 6. Pictures of the physical models made by the students.*
*"Ditt" - one of the three finalists*

Umbra chose "Ditt" (product 6: mail and key holder) as one of the three finalists, because its design reflects Umbra's brand accurately, and it is a simple and practical product. Some aspects (like proportions and materials) should be improved in the future in order to commercialize the product and find its right place in the market. The shaping of innovative products is complicated, because the intended new objects have no real 'predecessors' in their existence [7]. However, the most valuable part of this course experience is that students understand how design tools help them innovate with news forms and languages, while also having the opportunity to work with an international and expert design team. From the eleven products, five are closer to Umbra's language, according to Umbra's design team (products 1, 2, 6, 8 and 9 in Figure 6). They found these products to be very casual, innovative, modern and affordable; that fulfilled most of the requirements of the design's brief. On the other hand, the reason why the other six products don't match Umbra's language is because of the difficulty that some students have during form-giving in design. Using this methodology does not guarantee accurate results; some students are not capable of using the boards and applying them when defining the product's shape. From an institutional perspective, benefits include access to real-world problems, exposure to current industry, and enhanced standing in the community. For senior undergraduate students, this can be an excellent vehicle to test their skills before entering the workplace. For companies, it can afford access to fresh ideas and university resources otherwise beyond their means. Despite the clear benefits associated with university-industry collaboration, there are a number of challenges in the set-up and execution of such schemes [8]. A survey of the course's twelve students during the 2013-2 semester at Universidad EAFIT was conducted after the process. Answers to the questions are graded on a scale of 1 to 5, in which 5 is an "exceed expectations" mark and 1 a deficient evaluation. The following are some of the most relevant comments:

- Third-year students felt comfortable during the course, but said it was also very demanding.
- Design skills were achieved and also reinforced during the course, with a special emphasis on product semantics. Also, students felt they improved their communications abilities in a second language (English).
- All students said that the course was very fulfilling and that they would like to have more of the same type during their academic experience.
- Feedback received by students was very valuable and helped them continue keep going when the idea was good, or modify it when this was needed.
- Students would like to have more feedback from the Umbra's design team, which means that they would like to have contact more than three times so they can feel more close to the real world. They said that the company should also help them by choosing the product because since the company has the vision of the real market, they can better guide students to design more desirable products.

More results from the survey are shown in Figure 7.

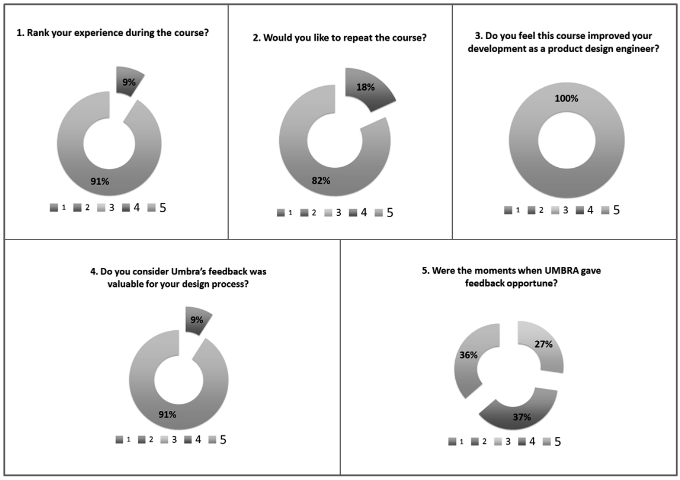


*Figure 7. Charts from the survey's results*

## 5 CONCLUSIONS

This paper describes an academic experience centred on the design process methodology used for home decor products at Umbra, within the context of an international collaboration format. The main purpose is to standardize this methodology for future courses, as part of the flexible curriculum at Product Design Engineering (Universidad EAFIT).

One of the methodology's key elements is that students use boards as a design tool, along with Umbra's feedback, in order to adjust the product shape to the company's brand identity, taking inspiring elements for designing innovative and original products.

From the product development opportunity, it is evident that academia and industry can work together well, and this adds significant value to both. It is like having a real client. Virtual feedback from Umbra's design team at three moments during the academic semester is a distinctive experience for our students, because they are confronted and pushed to give concrete and professional solutions for a real company.

The training that students receive to carry out their industrial semester with a higher level of competences and abilities is the most relevant aspect of the course, along with the practice of designing with an international design team that works with very prestigious design programs in the world; it provides a unique learning period for the student.

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# VIRTUAL PRODUCT ENGINEERING NETWORK CROSSES INDUSTRY AND UNIVERSITY CHASM

**Michael BITZER [1], Sebastian HANDSCHUH [1] and Martin LANGLOTZ [1]**
[1]Virtual Product Engineering – VPE Network Association, Germany

**ABSTRACT**

The engineering and design education across Europe can vary from countries and types of universities. With special focus on the situation in Germany this paper discusses an industrial view on the current situation in engineering and design education. Furthermore, the education in design engineering is mainly structured in engineering domains – e.g. mechanical engineering, electrical engineering and computer science. Established and new approaches – such as Product Lifecycle Management (PLM) or Systems Engineering – lead to new set of skills required from university educations.

The field of study "Virtual Product Engineering" (VPE) combines knowledge and skills cross classic engineering disciplines: mechanical engineering, electrical engineering and computer science. Home-based in this interdisciplinary environment the "VPE Network" was established to leverage on the one hand interdisciplinary education at universities and on the other hand benefit from an active network within the industrial base. The VPE network is an association founded in 2012 by former PhD students of the Institute for Virtual Product Engineering at the University of Kaiserslautern in Germany. The VPE Network is a community for knowledge and experience exchange of practitioners, students, researchers and friends.

This paper will conclude with a first resume on the work of the VPE Network and the presented approach. Moreover, further activities and topics are identified to enlarge the impact on design and engineering education and enable to bridge the identified chasm between industrial need and university offer in the context of engineering education.

*Keywords: Product Lifecycle Management, Virtual Product Engineering, Human Factors*

## 1 SITUATION TODAY – FOCUS ON GERMANY

The way the education in engineering and design is structured varies from global region and country. In Europe the education systems developed very heterogeneously over many years with missing interdisciplinary education in European Universities [1]. For this reason in 1992 the so called "Bologna Process" was defined to harmonize studies cross Europe [2]. Engineering studies were also in the focus of this approach.

With a special focus on the German university system this paper wants to elaborate the current situation to derive discussion and possible solution approaches. The education system in Germany had and still has mainly two types of universities: first the traditional "Full University" where the German Diploma was hold. Second, the "University of applied science" (German: Fachhochschule) where students graduated with a Diploma (FH). With the Bologna Process both types of Universities introduced the Bachelor and Master degrees and were allowed to award both grades.

Beside the type of university the basic structure of studies was segmented at German universities like in many other European countries. With a focus on the field of engineering studies, mainly the fields of mechanical engineering, electrical engineering and partially computer science were strictly divided in research silos or segments. Each field often is sub-divided in many faculties with specific research topics and educational focus.

Established and new approaches – such as Product Lifecycle Management (PLM) and Systems Engineering – lead to new set of skills required from university educations. Educational knowledge and skills required by graduates need to cross those silos and gaps to enable the right mixture of knowledge and skill set to address those approaches. As an example from industry, the importance of IT in the mechanical product "automotive" is pointed out by a statement of Matthias Ulbrich as CIO at Audi AG: "For Audi, information technology is a core competency" [3].

Based on these observations and ongoing discussions with universities and students this paper is proposing an approach to bridge this chasm – based on the example of the field of study of Virtual Product Engineering.

## 2 INDUSTRIAL REQUIREMENTS

From an industrial perspective this paper is focusing on manufacturing industries – including mechanical, automotive and aerospace industry. In those industry segments – especially within companies with strong roots in the German industrial base – the organizational structure is traditionally segmented according to the phases of the product lifecycle: Research & Development (R&D), engineering, manufacturing and after sales. Within R&D and engineering the organizational structure very often also represents similar fields as can be found at universities: mechanical, electric/electronic and IT.

Since a couple of years the above mentioned trends – such as Product Lifecycle Management and Systems Engineering – drive also activities, programs and finally organizational structures in manufacturing companies. This relates to new requirements towards required skill sets of the employees. For existing staff this might lead to a need of change in mind-set and skill set. For new joiner in companies this lead to new types of requirements in their education – reflected in published job advertisements.

From an educational point of view this implies two different types of challenges, which need to be addressed in education approaches to prepare students for the described situation in industrial practice [4]:

**Interdisciplinary knowledge**: Students working in an interdisciplinary environment or position within a company need to be able to understand discuss and add value in all involved functional areas.

**Social competence**: As a second dimension in this situation students need to be enabled to understand the challenges they might face when joining in an interdisciplinary position within a traditional manufacturing company. Employees who have been working in established and strongly segmented organization structures already for a long time might have strong difficulties with the new required way of working.

## 3 NEW APPROACH

The field of study "Virtual Product Engineering" (VPE) combines knowledge and skills cross classic engineering disciplines: mechanical engineering, electrical engineering and computer science. Home-based in this interdisciplinary environment the "VPE Network" was established to leverage on the one hand interdisciplinary education at university and on the other hand benefit from an active network within the industrial base. The VPE network is an association founded in 2012 by former PhD students of the Institute for Virtual Product Engineering at the University of Kaiserslautern in Germany. The VPE Network is a community for knowledge and experience exchange of practitioners, students, researchers and friends [5].

This paper will introduce the VPE Network approach and present first results and further outlooks on the following main areas:

**Engineering education**: Within this area the objective of the VPE Network is to provide industry-relevant topics and leading practice which can be leveraged in lectures and educations.

**Engineering internship & thesis**: Identified by the VPE Network as the major opportunity to experience "industrial reality" internships is in the special focus of the network approach. Out of the existing industrial network relevant internship positions are identified and pragmatically linked to active students at universities. By providing an informal and pragmatic platform students are supported in preparation of bachelor or master thesis. Industry-relevant topics and research questions are combined and tailored to individual situations – for students and respective company.

**Student trips**: As the opportunity to get "first insights" across many different companies the VPE Network is offering organized industry trips for students. As part of the overall approach students are offered to get in contact with different companies and by this providing both company and student the opportunity to exchange information and to network.

### 3.1 Engineering Education

The traditional education at universities is often focusing on theoretical knowledge as the basis for engineering capabilities. From an industrial perspective there are more competencies required to enable a graduate to perform in an industrial environment. For this reason many universities and institutes enlarged their offers for students with lectures including more dimensions than only theoretical knowledge. Typically those dimensions cover following aspects [6]:

- **Theory input:** For all relevant engineering disciplines of the respective lecture the required basic knowledge will be taught. This is typically split between relevant institutes and lectures.

- **Industrial focus:** Often based on alliances with universities and institutes companies provide real scenarios or existing challenges with some background information and data for the lecture.

- **Distributed team work:** As the work in industrial companies often is on a global and distributed level the student teams are faced with scenarios of distributed staffing and work split. It is possible to simulate such a situation by involving partner universities in the lecture situation.

- **Human factors:** Beside technical knowledge students realize the importance of performing as a team. The human factors or soft skills are as important as the technical skills in a collaborative situation.

To support such new formats of lectures in engineering education the VPE Network supports and coordinates contributions from industrial companies tolectures and practical courses. This helps to fulfill the objective of the association to enable exchange of information and experience in the context of engineering and design work.

### 3.2 Engineering Internship & Thesis

The collaboration of science and industry is one of the key enablers for continuous development and progress. Therefore many companies keep close cooperation with universities all over the world. The VPE Network and its members from different industrial branches are aware of this huge potential and support active students and PhD candidates in performing engineering thesis. Figure 1 shows the three main fields of interest in the pre-mentioned tension field (ref. Figure 1):

- Science
- Communities
- Industry

As Alumni of the institute VPE all members have a close cooperation to science and a lot of experience in this working field. Often active doctoral candidates or Alumni of the VPE are also involved in different industry and science communities. As an example Alumni of the VPE are often involved in working groups of the ProSTEP iViP association with focus on different topics such as Product Lifecycle Management, CAE or 3D- and structure data formats (e. g. ISO14306, ISO10303-242). As Alumni of course the main focus of the working field changed to work within the industry. There a broad range of different branches are covered by VPE Alumni's such as automotive, ship building, consulting etc. Of course also on industry side a lot of different work groups exist – with partly overlapping topics to the pre-mentioned communities and activities within science.

Now it gets obvious, that such a network build up on science activities, broaden within communities and industry is an enabler for new science and industry topics and connects highly educated experts from science, industry and communities. The connection within these different fields is shown abstractly by little documents exchanged between the science, industry and communities. The added value is therefore shown in the middle of this tension field (ref. Figure 1).

The VPE Network supports and connects students to industry partners and is platform for discussion. With their scientific background and industrial experience, the VPE Network members on the one hand help to prepare and create engineering thesis following scientific methodologies. On the other hand state of the art inputs from industry are provided. Especially in the context of VPE it is important to validate the solution concepts of engineering thesis against realistic use cases [7].
One example is an engineering thesis that has been carried out in a field of an upcoming ISO Standard, the STEP AP 242 Standard (ISO 10303-242). In this case the VPE Network provided a close collaboration in the tension field within science, industry and industrial communities. In this field many new and upcoming topics are discussed and developed. In this very fruitful working area many bachelor and master thesis were created, with benefits for both sides – science and industry.
The student worker even interacted in all three working areas. Beside science and industry the industrial communities – in this case the ProSTEP iViP association – were involved. The student worker made a very beneficial thesis in which a comparison of different formats (gap analysis) could help to create first industrial software prototypes on the one hand and to support the final development of an upcoming ISO Standard on the other hand.

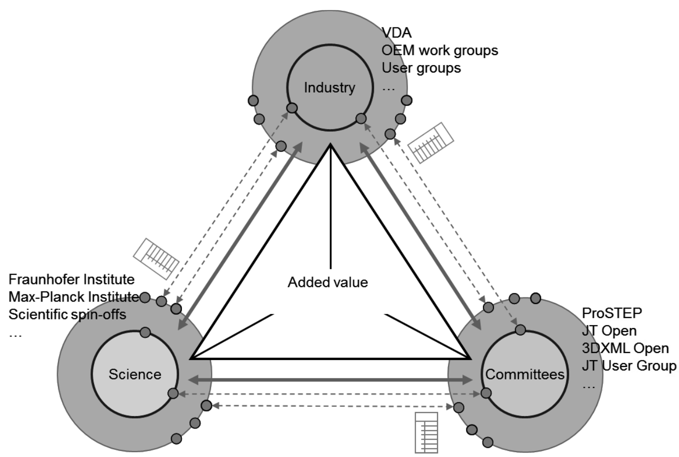


**Fig.1: Cooperation of science, industry and industry communities in the context of engineering thesis [8]**

Another example is an engineering thesis that aimed at a new solution concept for PLM-integrated Systems Engineering. It has been conducted by a student worker at :em engineering methods AG, a service company partnering in the VPE Network, and at the institute VPE. The intention of the student worker was to deliver a concept that is on the one hand beneficial from the point of real life industrial use cases and on the other hand raising the potentials of actual IT-solutions. In this case the challenge for the student worker was to elicit the broad topic of Systems Engineering in theory and industry while focusing on a solution concept that can be validated by a prototypical implementation. Therefore several workshops have been carried out with an industrial partner form the German automotive industry for the provision of use cases as well as for the validation of the solution concept and prototypical implementation. This close cooperation of all three partners from in the VPE network – industrial company, service company and research institute – is one of the major preconditions that made this engineering thesis successful.

### 3.3 Student excursions

Student excursions can be a key differentiator for both, students and industrial companies. The motivation of students to take part in excursions is mainly driven by the lack of knowledge about companies and the “real life” in business. Students want to get to know more about potential employers and their company culture. Moreover, students often believe that attending such events is positive for their CVs and demonstrate their motivation and passion as potential employee. On the other hand, companies often take the opportunity of supporting student excursion due to demands in new employees. Meaning companies want to position their brand as a potential employer as early as possible towards the future graduates.

The VPE network supports this idea together with the institute VPE and orchestrated a two day student excursion with a multi-industry-program. The program includes visits at several companies from the automotive and mechanical industry as well as a visit at a global service company. The tour provides a great opportunity to understand the spectrum of activities and potential jobs that can be addressed based on education in engineering and design. By this the VPE Network is trying to cross the often existing chasm between university education and expectation existing in industries.

The first “prototype” of such a student excursion will be launched in July 2014. Currently the VPE network, together with the respective institute, is finalizing the program of the two days and further preparation. At this point in time, first experiences show the very positive feedback of students, research students and university staff – even before the “official” marketing campaign was kicked-off.

Around 30 students and 5 research students will take part in this excursion. The major benefit for student and university perspective is the get insights in different companies and different types of “jobs of an engineer” in a very short time. On the other hand this is a great opportunity for students to figure out potential areas in industry where they might want to position themselves for entering the business world. For companies this event provides a great chance to present their company and inform the students about potential intern or trainee programs. Moreover, companies get direct access to very professional and specialized students in the field of engineering and especially Virtual Product Engineering.

Experiences made during these types of events will shape future excursions to continue bringing both sides closer – universities and industrial companies.

## 4 DISCUSSION

The VPE Network is an association originated in the area of research and education; trying to bridge both worlds: university and industry. At universities different kind of “alumni” groups and association do exist, with various types of focus. Having a closer look at the industry side a slightly different situation is depictured – and might provide some perspectives that can be adapted.

Especially in the service industry – where no physical products do exist and it is all about the human resource – networks and alumni programs are used to keep current and former employees together in some kind of community. From an outside-in perspective, this especially applies for those companies which are very focused and specialized in their services – and often combined with a high price segment.

## 5 CONCLUSION & OUTLOOK

This paper described aspects and point of views on the topic “design education” from an industrial perspective. The intention of this paper is to show where a “chasm” exists between education as it is done today and the requirements or expectations on young graduates which exist in industrial companies.

Moreover, a new approach for “crossing the chasm” was introduced – pointing out several aspects that the VPE Networks sees as critical to be addressed and which are aligned with activities of the association. This paper is part of these series of activities which the VPE Network wants to focus on – knowing at the same time that this can only be a starting point and that the approach and network will evolve and change over the time.

As one strategic initiative of the VPE Network, the launch of a new information platform is evaluated, where students are informed about specific opportunities in the area of virtual product engineering –

such as new internship, bachelor/master thesis or PhD work. The idea is to have not only open job descriptions provided, but also direct and personal contact into the respective companies via friends and members of the VPE Network. By this, the respective offers can be more easily tailored to the needs of the students – such as specific time constrains or adjustments on the bachelor/master thesis focus.

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# FACILITATING TRANSITION TO TEAM BASED DESIGN EDUCATION

**Christian TOLLESTRUP**
Aalborg University, Department of Architecture, Design and Media Technology

**ABSTRACT**
When students enrol in Problem Based Learning (PBL) and Project-oriented universities at Industrial Design programs, what are their expectations and prerequisites for starting to learn about design and work in teams with design? The short answer is: not as much as they think, studies shows that even if they had previous experience with project work in teams, they still encounter problems during their first semesters. So as a way to ease the transition from highly framed and facilitated high school learning context to university self-driven learning context a small experiment was carried out in 2011 and 2012 in form of a "Survival Kit". This paper investigates the long-term effect of the "Survival Kit" regarding the students' development in understanding the expectations towards them and the pitfalls in studying and working projects in teams through questionnaires given to two set of students; one set that received the survival kit in 2011 and 2012 and one set that did not. The questionnaire inquires the students' attitude towards 4 aspects:
1. General level of preparedness for team and problem based project work
2. Level of information of expectations from supervisors and programme
3. Reflection of the role in a team, problem based project work
4. The level of information of special expectations from the Industrial Design program towards team and problem based project work.

Results indicates that Class receiving the "Survival Kit" improved in the calibration of expectations and enhance students attitude towards dealing with development projects as an external professional activity, rather than an internal personal activity, thus increasing team-orientation.
The paper discusses the results and indications from the results in relation to creating a productive study environment and eases the transition into the learning context of a university.

*Keywords: Problem Based Learning (PBL), Design education, Facilitation, Survival Kit*

## 1 INTRODUCTION

A Problem Based Learning (PBL) and Project oriented Industrial Design Engineering program at a university can present a significant change in learning style and learning environment compared to High School and similar primary educations. Students have perhaps experienced group and teamwork before, the may also have experience working with minor, short projects. But for most parts the high school system is based on lectures, analytical reasoning and solving given tasks. So even if the students have these prior experiences, a full-scale PBL and project-oriented learning environment [1] represent a significant change and force the students to adapt their learning style and increase their self-reflection.
Besides the change in learning environment the subject of Industrial Design Engineering with the objective of creating 'new' solutions increases the transition even further, by adding the complexity of creating synthesis to the analytical skillset.
Within the creative professions there are many variations in relation to the role of the "designer" depending on the perception of the process ranging from black box to glass box [2]. In the black box the actual process of creation is a mystery and the talent of the individual is of the essence, this is what Stolterman [3] calls the artistic and aesthetic approach. In the glass box the process is transparent and knowing the methods, controlling the process and applying the tools is the essence – the individual it self becomes secondary and is described as the guideline approach [3]. Within Industrial Design Engineering programs in universities, the latter tend to be dominating as opposed to curricula in Schools of Architecture or Design Schools in a Scandinavian context.

The PBL based and project oriented Industrial Design Engineering program used in this investigation is very process focused with the objective of opening the process for engagement for all members in the design team. This is partly due to the structure and organization of the Programmes at the University, where almost all project activities throughout a curriculum are carried out in groups.

This challenge any student with a pre-perception of design as an individual, artistic profession, but at the same time it becomes very difficult to identify where and how the design is created since form-giving now becomes a group effort.

So the relation between the individual student expectation to them selves as performers and designers and the group effort, process management and decision-making becomes a pivot point for a design student's self-perception. This can create confusion and insecurity if students take criticism and feedback on project proposals personal, believing the content is more important than process of making it, i.e. an aesthetic approach rather than a guideline approach.

Furthermore the Industrial Design Engineering approach uses a different way of reasoning than the traditional models the students are accustomed to, the deductive and inductive reasoning. The third way of reasoning is abduction or productive reasoning [4], where the designer works from assumptions, based on quick analysis of wicked problems [5] and suggests a potential 'correct' solution encompassing both quantitative and qualitative aspects. This suggestive approach is linking closely to the reflection in and on action [6], where the systematic and continuous learning cycle [7] is the key to progressing in the process.

The Industrial Design Engineering curriculum summarises these aspects in the following definition of the design process: "*The Design Engineering process is fundamentally a technical and scientific product development process, in which analysis and synthesis of social and human science aspects in relation to needs, sales and use of products and solutions are systematically and methodically integrated through externalization and abductive reasoning, capable of handling wicked problems and open-ended processes.*"

So when students take on the transition from the high school systems to the university and the Industrial Design Program, how well prepared are they and how can we facilitate this transition?

This was the question in 2012, where a small group of faculty from the Industrial Design Engineering program decided to try addressing this issue by creating a "Survival Kit to studying an Industrial Design Engineering Program".

## 2 METHOD

### 2.1 "Survival Kit": A lecture on dogmas

The first "Survival Kit" can best be described as a lecture on 13 dogmas for studying Industrial Design Engineering based on experiences from 3 staff members, whereof 2 where former students providing an 'inside' perspective on things with personal anecdotes and experiences. Most of these dogmas, rules and recommendations, are related to the way design engineering is perceived and practiced in the Programme, but a few are related to other more general aspects of being a student.

In Table 1 a run-through of the dogmas illustrates the relation to the previous mentioned aspects of Industrial Design Engineering.

*Table 1. Dogmas of Survival Kit 1*

| Dogma | Statements | Relation to Design Engineering |
|---|---|---|
| 1:<br>Prototype it | "Make it – test it", "You can't think your way to a solution" and "You can't discuss your way to a solution" | Strongly related to the suggestive, abductive approach with the encouragement to generate actual proposals to help the testing (externalization process) and drive the process forward. |
| 2:<br>Take ownership in ideas from others | "Share ideas", "Give your ideas away" and "Take ownership in ideas from others". | This relates to the perception that designing is not a black box where the ownership is important, it is the process that is important and ideas are just stepping stones. |
| 3: | "We don't want to hear: Is this | This dogma relates both to the fact that there is |

| | | |
|---|---|---|
| Responsible for your own learning | good enough and what shall we do now?", "We want you to learn to do it your selves" | no one single correct answer to wicked problems. And secondly the general idea of studying a subject is a self-driven process, rather than being tutored and taught as in high school systems. |
| 4:<br>Get up and study | "Make your own profile and possibilities", "Make sure you learn what you find interesting", "Are you not content: act and seek out what you miss", "We cannot teach you everything". | As with the previous dogma, this places the responsibility of learning and studying with the student, but underlines the point that students need to create a personal professional profile during the studies. |
| 5:<br>Connecting the dots | "You haven't got the overview yet and may not see the underlying reasons for every subject", "It does not mean it is useless, just that you haven't got the overview yet", "The learning is brought to you by experts" | A curriculum is progressively built, so some subjects may be the foundation for later subjects and not other concurrent ones. Also there is a difference between high school systems where a certain subject is *taught* by a teacher and universities where a subject is *studied* supported by a researcher). |
| 6:<br>We are not artists, we are craftsmen | "It is OK not to feel creative", "Creativity is a tool you learn how to use", "Our profession is a craft that requires skills" | This glass-box oriented dogma is countering the perception of a certain creative talent is required to engage with the field of Industrial Design Engineering. |
| 7:<br>We communicate visually | "There must not be a barrier between you and what you want to express", "Draw", "Form is not described with words: show it!" | With these statements this dogma is an equivalent to dogma 1, aiming at supporting the abductive reasoning by generating material for communication with external parties and stakeholders. |
| 8:<br>There is no one right answer. | "You can not analyse your way forward", "Try you way forward", "Fail often, it will bring you closer to an answer" | This dogma is a very direct support to wicked-problems, open ended processes and the abductive reasoning. |
| 9:<br>We are not criticizing you, but your proposals. | "Do not take it personally", "Learning from mistakes are better than learning from success", "Learn a lot, do not play it safe" | This dogma tries to combine the inherent learning process in design with a more professional attitude towards receiving feedback (criticism) on a proposal, leaning towards the guideline approach rather than the aesthetic. |
| 10: Girls wake up. | "Use 3D software", "Use the workshop", "Dismantle something", "Look out or the boys will leave you behind" | This dogma speaks to the experience that using 3D software and focusing on the constructional aspects usually is predominant within male students while female students tend to ignore this. |
| 11:<br>Boys, don't fall into the hole. | "It is important to know more than just one thing" | This dogma reverses dogma 10 and encourages the male students to cope with the entire design process, not just construction and 3D modelling. |
| 12:<br>Working in groups is difficult. | "Be patient", "Do not get upset if offended", "Help each other to learn" and "Say what you feel, not just what you mean" | This dogma acknowledges the fact that working together professionally is a challenge, and takes some time getting accustomed to. |
| 13:<br>Get a life | "Have a hobby", "Do physical exercises", "Find somewhere else to recharge your batteries" and "Get a part-time job" | This dogma is merely aiming at promoting a healthy study environment and a more pragmatic approach to the studying, not seeing it as 24 hours work and lifestyle, but rather promoting a professional attitude from the beginning. |

## 2.2 The survey

The “Survival Kit” was only a 2-hour lecture out of a 900 hours pr. semester workload for the students and may not have left much of an impact in itself. But the increased focus on being explicit and facilitating the transition may have left an impact. Therefore a questionnaire was given to 2 classes, one starting the Bachelor Program in Industrial Design Engineering in 2010 who did not receive any specific or explicit attention to the transition (Class A) and one class starting the Bachelor Program in 2011 who received Survival Kit I on their 2$^{nd}$ semester and Survival Kit II on their 3$^{rd}$ semester (Class B).

The survey covers 4 main lines of questioning concerning the students own perception of their level of preparedness and the potential change is this during the first 3 semesters in the program. The Survival Kit is not mentioned in the questionnaire in order to avoid bias and leading questions; only the level of preparedness in 4 different aspects in used.

### *2.2.1 Question 1: Team based project work in PBL*

First question is “Aalborg University utilizes a study format of project work in teams. How well prepared were you to work in team based project work within Problem Based Learning on your first 3 semesters?” This question seeks to investigate issues from dogmas 3, 4 and 12 related to responsibility for ones own learning and attitude towards seeking information and knowledge in a pro-active manner, as well as understanding the difficulty and effort a team based project requires.

### *2.2.2 Question 2: Studying a creative profession*

Second question is “There is a difference between studying a creative profession at the University and your former educational activities. How clearly was the expectation towards you as a student communicated by the Program, Project coordinators, supervisors, lecturers, etc.?”

This question investigates issues related to dogma 5, 6 and 8 concerning the overall perception of a university curriculum as something that is not set in stone and the subject matter is influenced by qualitative aspects (human and social science), that does not lead to one right answer.

### *2.2.3 Question 3: Role in team work*

Third question is “There are many ways to engage in team work, to what degree did you feel comfortable with and understood your own role?”

This question investigate the self-reflection on the students own potential strengths and weaknesses, some of them exemplified in dogma 10 and 11 concerning gender specific pitfalls and dogma 2 concerning engaging co-creational activities.

### *2.2.4 Question 4: Industrial Design specific approach*

Fourth question: “The Industrial Design Engineering Program has expectations of the professional subjects and the way you approach a project. How clearly were these expectations towards you as a student during the first 3 semesters?”

This question investigates the students attitude to the issues of producing material, visual or models (dogma 1 and 7) as an integrated part of the design process, as well as necessary feedback loop on content (dogma 9) and the professional attitude of the profession being a job rather than a lifestyle (dogma 13).

# 3 RESULTS

The survey results are divided in the 4 main categories with varying percentage of response, which renders the results on question one very uncertain and will be omitted.

## 3.1 Studying a creative profession

The most interesting difference between the classes in relation to question 2 shows that the increase in clarity was significantly larger in the “Survival Kit” class (Class B) than the Class not receiving the Survival Kit (Class A) as shown in Figure 1.

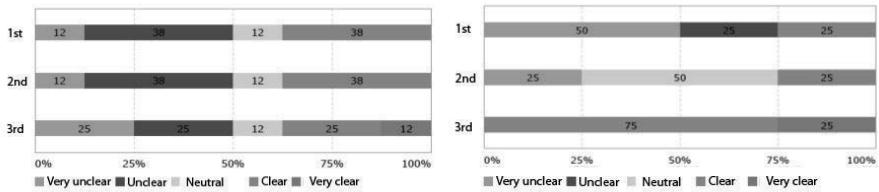


*Figure 1. Class A on the left, Class B on the right*

Class A shows no difference in the perception between the first 2 semesters, and a slight increase from 2nd to 3rd semester in the top of clarity (Very clear), but it is balanced by a similar increase in the absolute bottom (Very unclear). Class A differs significantly and show a steady progress throughout the 3 semesters, ending with only "Clear" and "Very clear" answers. The most significant leap is from 2nd to 3rd.

The comments received indicated that most significant for the clarity in how to study a creative profession was *"Study guide and occasionally lecturers and supervisors"*.

### 3.2 Engaging in team work

In Figure 2 Class A shows that approximately 50% are "Comfortable" and feel at ease with their own role in a project team, and the development over the 3 first semesters show only a slight improvement from 1st to 2nd semester. Class B shows a very significant progression with all respondents being from average and below in the 1st semester to all respondents being above average "Comfortably" or "Very comfortably".

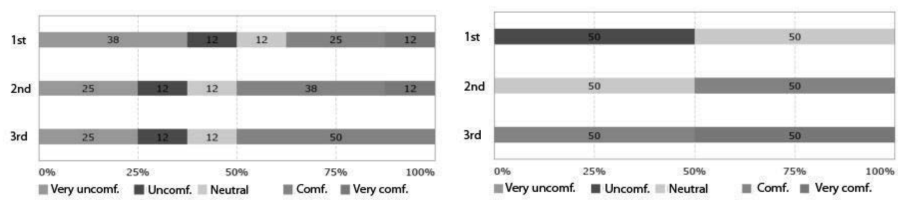


*Figure 2. Class A on the left, Class B on the right*

### 3.3 Industrial Design specific approach to project work

In Figure 3 Class A shows almost no change over the 3 first semesters of the Bachelor programme, except for a very little change from 1st to 2nd semester. This is interesting considering the fact that Industrial Design was introduced on 2nd semester in a short project and the entire 3rd semester was exclusively Industrial Design Engineering. Class B shows another interesting change: a 100% "Above average" understanding on 1st and 2nd semester changing to 50% "Average clarity" and 50% "Very Clear".

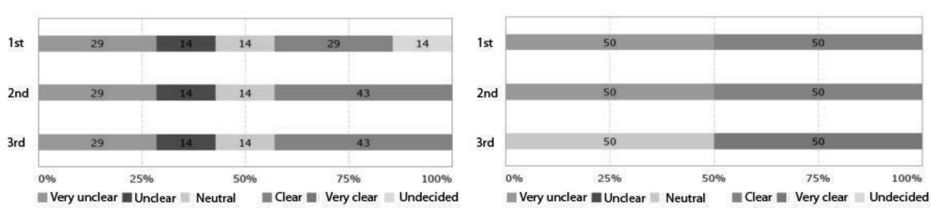


*Figure 3. Class A on the left, Class B on the right*

## 4 CONCLUSION AND DISCUSSION

One could argue the validity of the connection between the subject of the Survival Kit, the impact of a 2 hours lecture and the relation to the line of questioning. But as indicated earlier the shift in focus on

the peripheral and transitional aspects around the PBL project-oriented study of design engineering may in it self also has contributed to an increased awareness amongst students.
The main learning points from this small investigation is that focusing on communicating expectation towards attitude, engagement and commitment in the study of Industrial Design Engineering can increase the awareness and clarity of understanding the professional field as well as how to engage the study environment. The survey indicates that students can be 'moved' by little effort and focus on the matter, but there is no clear evidence in terms of absolutes, only the relative increase.
Furthermore the positioning of what type of "design" the program represent and the subsequent consequences in are important to continuously develop and communicate. When operating towards a glass-box perspective it has explicit consequences in terms of expectation towards student behaviour and attitude in a team based project.

### 4.1 Future perspective

This little experiment indicates that there could be a potential increase in students learning and willingness to study and experiment in the Industrial Design Engineering programme by being more explicit in the communication and facilitating the entry into the university system in the first few semesters. It is important to more explicitly put the expectations into perspective of both the professional field of study as well as the study environment as a project-oriented Problem Based Learning stage. This stage is important to stress that the responsibility of learning is on the student's shoulders, since learning is such an inherent part of the abductive reasoning in the design process that you cannot outsource the learning responsibility to "teaching" activities from lectures and supervisor. Stating the responsibility will not be enough to make a difference, it is equally important that the evaluation mechanisms support and rewards students that demonstrate the ability and willingness to study phenomena during a project, even if they are slightly out of scope of the official curriculum and specific learning objectives. But we need more investigation into what approaches, methods and organization of activities that helps create a culture of studying and exploring the field in a design engineering education context.

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# FLYABLE – DESIGN OF FUSELAGE FOR TWO SEATER AIRCRAFT TO BE FLOWN BY A DISABLED PILOT: LEARNING OUTCOMES FROM DIFFERENT APPROACHES TO LECTURES

**Katherine FROST, Sara LINDA, Ahmed KOVACEVIC and Sham RANE**
City University London

**ABSTRACT**

EGPR (European Global Product Realisation) is an undergraduate project, which involves collaboration between 5 European universities and an industrial partner. The aim of the course is to develop students' engineering design skills and to build confidence in being part of a team in different locations.

Usually, engineering students are placed in international teams, which use videoconferencing tools to hold regular meetings and online storage facilities to share documents. Videoconferencing tools are also used to enable all students to attend lectures given by staff from the participating universities. At the end of each design phase reviews are held where each team presents and produces a report showing their main findings or deliverables. The design process and deliverables from the EGPR project held from February to June 2013 are explained in this report.

Lectures delivered by staff through two EGPR projects have been evaluated. The first project involved only engineering students and lectures were task-based according to the design stage that the students were at. The second project involved both engineering and product design students, and the lecture content was initially more focused on developing team-building skills. It was decided to investigate how this difference in lecture content affected student satisfaction and their learning outcomes, as students who participated in both projects noticed a great difference between the two.

A questionnaire was distributed among students who had taken either or both of the EGPR projects mentioned. Information gathered included an overall rating of the lectures; a choice of preferred lectures; and reasons for the certain lectures being preferred.

The results of the questionnaire showed that overall satisfaction was much higher for the first project, as the lectures helped guide the students through the design process step-by-step. The lectures of the second project were found to be enjoyable and interesting to students, but they struggled to apply the material to their own situation.

*Keywords: Engineering design process, international team, task-based, team-based, lecture content*

## 1 INTRODUCTION

EGPR is a group project module taken by students in participating European universities that offers the opportunity to develop engineering problem solving skills and provides the experience of working in an international team in conjunction with an industrial partner. Students take part in a preliminary conceptual design project from October to January which helps prepare them for the more difficult realisable design project, which runs from February to June.

From February to June 2013, engineering students from universities in Bristol, Budapest, Ljubljana, London and Zagreb completed a project with the aim to design and build a prototype fuselage for disabled pilots. The design project was named 'Flyable'.

To solve the design problem, 5 teams were formed, all consisting of members from each participating university. Through 5 project phases the teams followed the engineering design process by attending lectures, holding meetings and developing their knowledge and understanding of the brief until a detailed design had been produced and approved.

All participating staff and students attended a residential week-long final workshop in the UK, where the students manufactured a full-sized prototype airplane and wheelchair. In testing, a person using the wheelchair could enter, demonstrate use of, and leave the airplane unaided; showing the potential and suitability of the design for further development. This report gives a detailed description of the progression of the Flyable project.

From October 2013 to January 2014 a new group of students joined the EGPR course and undertook the task to design and build a more effective aeroplane tray table. Two of the students had previously taken the Flyable project. A more detailed description of this project is available [1].

The teaching approach for each project varied into two distinct styles: the Flyable project was very much task-based, and the tray table project was team building based. The lecture titles for each project are presented in this paper and the objective is to determine how the lectures affected student satisfaction and their learning outcomes.

## 2 PROJECT DESCRIPTION

The industrial partner for the 2013 main project was Condor Projects Ltd., a specialist contractor to the civil engineering industry. Condor Projects Ltd. defined the design problem as the owner of the company, Martyn Wiseman, had a keen interest in aircraft. A friend of his, who he had once enjoyed flying with, unfortunately had a severe stroke and was left unable to talk or walk. Mr. Wiseman took his friend flying as a passenger in his light aircraft and found that once in the air his friend was able to operate the plane just as he had before his stroke.

Mr. Wiseman began researching planes with hand controls and disabled access and found that there was no complete solution in the existing market: planes could be modified to suit the user's needs but these modifications were often cumbersome, expensive and required input from another person. Mr. Wiseman contacted the engineering departments of several UK universities and eventually came into contact with City University, and it was suggested that the prototype be developed within the EGPR course. The official project task was 'design and optimisation of the fuselage for an airplane to be flown by disabled people', which was later extended to include design of the whole airplane.

In February 2013 students taking part in the EGPR course were introduced to Condor Projects and the coaches and members from the other universities. Members were informed of which team they had been placed in so that a good mix of subject areas, and therefore skills, was established. The general timeline and plan of the project was described, so that at least one cycle of an engineering design process could be completed by the end date.

## 3 PROJECT TIMELINE AND DELIVERABLES

The total time (disregarding assessment periods) spent on this project by students was 14.5 weeks. The engineering design process was followed in five stages, namely research; concept development; preliminary design; detailed design; and manufacturing. At the end of each design phase each team produced a report and gave a 15 minute presentation to the company, university staff and their peers. The main tasks and deliverables from each stage are summarised in this section.

### 3.1 Research

Each team conducted general and overall research, but with an emphasis on the area or task given in Table 1. The research phase lasted for 4 weeks in total.

*Table 1. Review of team's tasks during phase 1*

| Team | Research area or task | Main findings |
|---|---|---|
| Team 1 | Existing aircraft and modification methods, licensing regulations. | Several modifications available for hand controls, access always requires auxiliary mechanism. Limits to be adhered to for airworthiness. |
| Team 2 | Define requirements. | Weighted objectives list made, contact established with supporting charities and organisations. |
| Team 3 | Aircraft structure, components and cockpit layout. | Knowledge of typical layout, arrangement of masses, and issues important to a buyer. |
| Team 4 | Company and market, user and usage, normatives. | UK market size of about 20 planes, potentially more with injured service people returning from conflicts. Industry standards for several countries. Problems encountered by people in wheelchairs. |
| Team 5 | Functions of each component, | List of pros and cons of different aircraft configurations |
| | design problems of each. | (tractor vs pusher, high wing vs low wing etc.) |

### 3.2 Conceptual Design

The Conceptual design phase lasted for 2.5 weeks. Following feedback from coaches and Condor Projects, each team had to come up with at least three complete solutions to the design problem, each with descriptions of the process of usage, potential advantages and disadvantages, and a functional model. The details were provided in a report and presentation from each team.
Over 20 different aircraft configurations were suggested, with some examples shown in Figure 1.

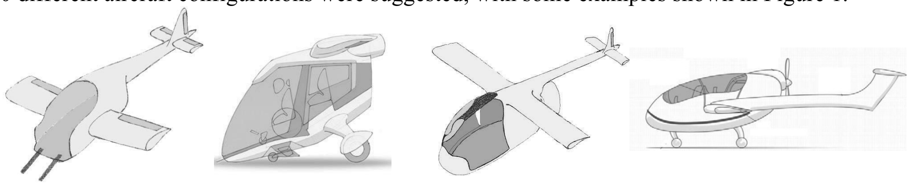

*Figure 1. Examples of aircraft configurations produced by teams*

### 3.3 Preliminary/Embodiment Design

An aircraft configuration which was recommended by students had twin booms, a puller configuration, and access for the pilot via a ramp at the rear which, when closed, was also part of the fuselage. This design is shown in Figure 2.

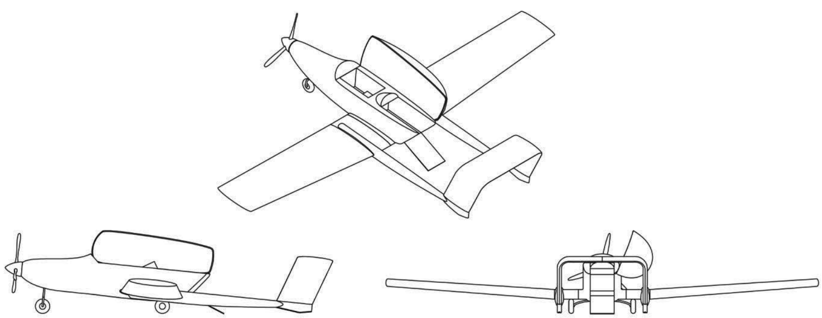

*Figure 2. The configuration which was chosen as the basic overall design for all teams to work on*

This design was proposed based on the use of the decision matrix and technical-economy diagram and was accepted as the design for all teams to work on by the supervisors of teams and the company.
The embodiment design phase lasted a further 2.5 weeks. Each team was assigned a specific area of the aircraft to concentrate on for embodiment design.

- Team 1: Control system design and interior design;
- Team 2: Engine mounting, fuel tank, landing gear;
- Team 3: Wheelchair;
- Team 4: Ramp/door and overhead canopy; and
- Team 5: Frame design.

As could be expected, many tasks crossed over between the teams and so required regular correspondence. For example, team 4 needed to inform team 5 of any changes made to the ramp so that the frame design could be changed accordingly, and vice versa. To help to organise cross-team communication, a new team was formed from selected members of the existing five teams and was called the cross-team board (CTB).
At the end of this phase each team submitted several proposals for designs of specific components for their respective tasks. Although the decision on the aircraft configuration had been made and teams had completed the preliminary embodied design so that the project could be moved into the detailed design phase, some large changes were about to happen in the detailed design phase.

## 3.4 Detailed Design

The detailed design phase lasted for 4 weeks. Feedback provided to the teams gave guidance on which of their conceptual ideas had potential for development and which were not suitable. Using this feedback, the teams used decision making methods to determine which of their sub-assemblies should be chosen for detailed design, with the chosen outcome maximising both technical and economical requirements. After deciding on concepts of sub-assemblies, teams proceeded with detailed design of these components and were required to provide all necessary documents for manufacturing, including 3D models, CAD drawings, and a Bill of Materials (BOM).

A large amount of the time during this phase was spent by each team making small changes to their designs to ensure that they fitted in with the other sub-assemblies. The CTB was responsible for assembling all these components and sub-assemblies provided, which were in hundreds. The CTB took into account mass distribution, airworthiness, stability and other aspects of the design. It occurred that in order to make the aircraft statically stable and manoeuvrable in flight, some drastic changes had to be made, namely it was necessary to replace the twin boom to a single boom as shown in Figure 3.

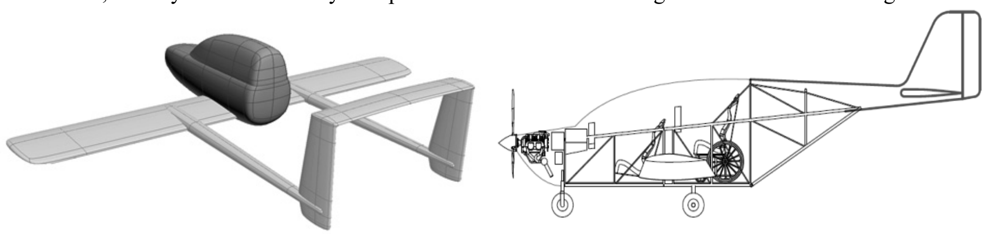

*Figure 3. The design expected at the start of phase 4 (left) and the actual design at the end of phase 4 (right) [2]*

*Figure 4. The final 3D design of the aircraft design to be flown by disabled people*

As this major change happened at such a late stage it could have proved difficult to complete all tasks on time, but it actually provided an opportunity for teams to improve certain aspects of their design that had been restricted beforehand. For example, the ramp had previously been limited in length, meaning that the wheelchair had to climb a slope of 30°. The change of design allowed the ramp to have an incline of 14°, which could be climbed by the electric wheelchair designed for this purpose.

At the end of this phase, teams presented and documented the final sub-assemblies, and the CTB presented the final design of the aircraft, shown in figure 4.

## 3.5 Manufacturing

The manufacturing phase lasted for 1.5 weeks. Before the students' arrival in London for the final workshop, employees of Condor Projects Ltd had begun the sourcing of materials and manufacture of the prototype. Upon their arrival students were given full access to professional workshop facilities including water jet cutters and welders.

By the end of the phase, and the project, students had produced a steel frame, half of the model's skin, a ramp, a firewall, and a working electric wheelchair. Images of the prototype are shown in Figure 5.

*Figure 5. Photographs of the prototype model at the final workshop*

On the day of the final workshop the prototype was presented to university academics and industry professionals who were generally impressed by the depth of knowledge developed by students and the amount that had been achieved in the allocated time.

## 4 TEACHING MATCHED TO TASKS

Throughout the Flyable project, lectures were tailored to suit the tasks that the students were undergoing. For example, the course began with a lecture on the engineering design process so that all students were familiar with the style and order in which coaches and the company wanted work delivered. The number of lectures given each week decreased over the course of the project as students undertook more detailed and specific work, until there were no lectures given during the manufacturing phase. The summary of lectures given to students is shown in Table 2.

*Table 2. For the Flyable project the lectures were tailored to help students with their current or a future design phase*

| Design phase | Lectures given |
|---|---|
| Research | 'Project presentation and deliverables'; 'Static stability of small aircraft'; 'Creativity in design'; 'Control systems of small aircraft'; 'Design process: functional decomposition, concept generation and evaluation'; 'Ergonomics and human factors: interaction between user and device' |
| Preliminary design | 'An engineer's guide to intellectual property law'; 'Use of the DesignVUE tool'; 'Structural design of an aircraft fuselage'; 'Economy and costs in design'; 'Detailed designing' |
| Concept development | 'Materials and technology for small aircraft' |
| Detailed design | 'Manufacturing methods' |

## 5 COMPARISON WITH OTHER TEACHING STYLE

From October 2013 to January 2014 a new group of EGPR students began the course, with two members being allowed to carry on from the previous group for a second year (the authors of this paper). A conceptual design project was completed with the aim being for teams of engineering and product design students to design and build a more effective aeroplane tray table. The partaking universities were the University of Malta, the University of Strathclyde and City University London.

The setup of EGPR projects is always the same, with each of the universities giving lectures on issues relevant to the students. The lecture content used in this project, however, differed from the previous one, as the methodology of design process was not the main focus. Instead, introductory lectures focused on creating awareness of the differences between and difficulties faced by team members in different locations. A strong emphasis was placed on promoting strong team cohesion and easing the collaborative process.

A summary of the lectures delivered over the project is given in Table 3.

*Table 3. Lectures given were aimed at helping distance teams collaborate*

| Design phase | Lectures given |
|---|---|
| Weeks 1-4 | 'Introduction: assessment and relevant literature'; 'Project briefing and culture'; 'Teams'; 'Distributed project management'. |
| Weeks 5-8 | 'Global working', 'Causal maps'; 'EGPR: European Global Product Realisation'; 'Selecting concepts'; 'Detailed drawings and rough models'. |
| Weeks 9-12 | 'Critical design information'. |

## 7 FEEDBACK AND LEARNING OUTCOMES

An anonymous-response questionnaire was distributed among students who had taken part in either or both of the mentioned EGPR projects. The questionnaire asked students which project they had participated in, and how they found the lectures on the scale between extremely useful (response =5) or not helpful at all (response =1). Students were then asked to name their preferred lectures from the lists provided in Table 2 and Table 3; and then to give reasons why it was their preferred lecture. It should be noted that the vast majority of responses were probably from engineering students, who, due to familiarity with the questionnaire author and distributor, may account for a higher proportion of responses than product design students.

For students who responded that they had taken the Flyable project the average response to overall lecture rating was 4.5. The most commonly selected preferred lectures and some of the quotes given for reasons why are listed:

- 'Project presentation and deliverables' – "The problem was made very clear. Knowing what was expected of us early on helped me plan in my head how I could tackle the design problem and made me think and link ahead rather than work on one thing at a time".
- 'Creativity in design' – "It gave a clear understanding on processes and tools needed to be employed to complete the project".
- 'Detailed designing' – "Advice on how to approach detailed design as a large team was helpful"

For students who responded that they had taken the aeroplane tray table project the average response to overall lecture rating was 2.5. Attention at this point should be drawn again to the increased probability of the response being from an engineering student, who was unfamiliar with the lecture content compared to a product design student.

The most commonly selected preferred lectures and some of the reasons why are listed:

- 'Global working' – "This lecture gave interesting examples of global design in action and I gained a new insight on how multinational companies operate."
- 'Cultural differences' – "This was a really interesting lecture in terms of learning about other cultures but I didn't really see how it applied to my project. The people in my team were just like the people I usually spend time with so I didn't need to be sensitive to their culture".
- 'Causal maps' – "Seeing a new way of doing a familiar task was useful. Seeing the similarities between causal mapping and the techniques I am used to made me think that the design processes aren't too different and we managed to mix of our skills because of this".

## 8 CONCLUSION

The responses from the questionnaire showed satisfaction with the quality and timing of lectures, especially for the Flyable project. Students felt the Flyable lectures were tailored to their needs and addressed issues that they were facing. For the tray table project, students found the lectures interesting but did not have the opportunity to practice the team building-skills that they had learned of as their new team members were relatively 'normal' to them and required no special considerations for cultural differences.

From further response inspection, it can be interpreted that team performance did not suffer due to the distance between members or cultural differences. There were some team problems encountered during the tray table project as not all students were familiar with using the same design techniques, and arguments over which design tools to use occurred. However, in some cases students relished the opportunity of learning a new technique and this was facilitated by the lectures given.

Overall, the findings point towards task-based lectures improving student understanding and ease of progression. However, these projects were both based within Europe and therefore all students shared a common culture – if the project was worldwide and involved students from alternative cultures then it is highly likely that the team-building education would have proven extremely useful and applicable.

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Chapter 9

# DESIGN EDUCATION IN PRACTICE

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
4 & 5 SEPTEMBER 2014, UNIVERSITY OF TWENTE, THE NETHERLANDS

# FROM LEARNING TO EXPERIENCING PRINCIPLES OF ENGINEERING DESIGN AT THE TUM

**Ioanna MICHAILIDOU, Michael ROTH and Udo LINDEMANN**
Institute of Product Development, Technische Universität München

**ABSTRACT**
The lecture "Principles of engineering design and production systems" is a lecture attended by Bachelor students in their second semester of studies in mechanical engineering at the Technische Universität München. Since April 2013, the lecture has been extended by a student project, in which the approx. 800 participants, divided in groups of 15, were asked to carry out a development process and conceptualize an innovative product by applying the contents taught in the lecture. The goal was to increase the learning effect of the course through the benefits of experiential learning and project work. The participants are expected to develop technical and social skills, which are important for their future career as engineers. The motivation for restructuring the course, the contents of lecture and project, observations and feedback collected after the first project completion, as well as improvement suggestions are presented in this paper.

*Keywords: Engineering education, student project, design methods*

## 1 INTRODUCTION

For the past 50 years, engineering education has been science-based, stressing analytical, problem solving skills rather than the broader skills of engineering design, systems integration and innovation. A deep technical education in the engineering field chosen is, of course, essential. But a large set of additional skills, ranging from creativity and innovation to life-long learning are equally important for modern engineers. At the Technische Universität München, the lecture "Principles of engineering design and production systems" is a lecture attended by Bachelor students in their second semester of studies in mechanical engineering. In the lecture, theoretical foundations for development of technical products are being taught. Since April 2013, the lecture has been extended by a student project, in which the approx. 800 participants, divided in groups of 15, were asked to carry out an exemplary development process and conceptualize an innovative product by applying the contents taught in the lecture. Through the new project-oriented structure students are supposed to gain a better understanding of the theory presented in the lecture and increase their technical and social competences.
Goals and advantages of experiential learning and project work in engineering education, as well as the motivation for restructuring the course are presented in section 2. The contents of lecture and project are described in section 3, while lessons learnt based on observations and feedback collected after the first project completion are presented in section 4.

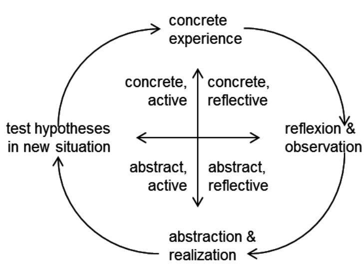
## 2 BACKGROUND, MOTIVATION AND GOALS

### 2.1 Experiential learning and project work in engineering education

The learning outcomes of engineering education should be useful for universities but also for the society. Using academic learning for increasing employability and citizenship requires multidisciplinary, subject-related competencies [1]. The importance of those competences in the field of engineering is emphasized by VDI [2]. They claim that, beside the 30% fundamentals of mathematics and natural sciences and 30% for fundamentals of engineering, the structure of engineering studies should involve 20% application-oriented basic knowledge and engineering-based problem-solving methodology and 20% multidisciplinary skills. A study of VDMA in 2004 [3] reflects the some idea concerning mechanical engineering in practice: 80% of the enterprises asked wished for more interdisciplinary knowledge as well as social and methodical competences from their employees. 70% confirmed that education should be more praxis-oriented, while 60% had no wish for the theoretical knowledge to be extended. A practitioners' profile analysis conducted by Brandstetter [4] shows that social, personal and methodical competences play a vital role for German engineering enterprises. There are a number of modern teaching methods which aim at increasing those competences, including the approaches of: experiential learning, open classes, free labour, project learning, hands-on learning, action-oriented teaching, and Freinet Education [5]. In following sections, the approaches of experiential learning and project work are analysed, as most relevant for the agenda of the Technische Universität München and for the course selected.

#### *2.1.1 Experiential learning*

Experiential learning is the process of production of meaning through direct experience. The theory of experiential learning bases on the work of Dewey -from the field of philosophy, Lewin –with focus on team dynamics, and Piaget -learning as interaction process, but has been founded by D. A. Kolb [6]. The term "experiential learning" describes learning which results from direct participation in the events of life. It refers to a holistic approach to learning, combining experience, perception, cognition and behaviour. According to the experiential approach, learning is the process in which knowledge is created through the transformation of experience. It requires direct contact with the phenomenon being studied, rather than simply studying or reflecting it. Experiential learning involves analysis and initiative and, opposed to academic learning, is not reproductive. No teacher is required and learning relates only to the process of directly experiencing. The learning process is individual and requires therefore some conditions, such as the student being willing to engage actively, being able to reflect upon their experiences, having the capacity to understand the experience and decision making skills to use the new knowledge.




Experiential learning
…builds on the experiences of students or causes new experiences.
…encourages students to participate actively in the learning process and to invest personal interest in it.
…urges to explore and discover, while it activates imagination and creativity, promoting students´ self-awareness.
…urges to find or create meaning instead of memorizing information.
…considers an integrated mental and emotional process, since learning is based on the relationship and interaction of knowledge and emotional processes.

*Figure 1. Kolb's experiential learning circle [6] and principles of experiential learning [7]*

#### *2.1.2 Project work*

In project work it comes to an acting-teaching process on a concrete task. Within the framework of a project, emphasis is put upon practical realization by the participants and self-planning and self-responsibility are required. According to the definition of a project in DIN 69901, a project takes place in unique conditions, has a specific target goal (concerning time, financial and personal aspects), and is realized by a unique plan in a project-specific organization. Other dimensions of projects beside uniqueness are: complexity, interdisciplinarity, team-work and significance [8]. The learning objective of project work is to increase the participants' competences in: methodological proceeding towards a solution, autonomous work, documentation and further use of the results, working economics, critique skills, subject-specific knowledge, collaboration and communication. Thus project work forms the basis for collaborative and research-based learning in studies [9]. According to [4], project work and learning through research are the most effective teaching and learning methods in engineering education, when organizations and their members go new ways in the context of key competences. These course forms represent an effective combination of technical, methodological and social skills, when: The basis of the project is constituted by a research question, a project- or problem-solving task with technical content; Students are provided knowledge of methods such as project and time management, creativity techniques and models on teamwork and communication within preparation workshops; Team meetings are process-oriented and closely and continuously supervised and reflected by and with teachers.

Those characteristics of project work and requirements for its effective application have been taken into consideration for creating a new teaching concept for the lecture “Principles of engineering design and production systems”.

### 2.2 Motivation for restructuring the lecture

The motivation for restructuring the lecture “Principles of engineering design and production systems” was to increase the learning effect and support students in the transfer process of academic knowledge into engineering design application. The combination of theory and application should reinforce a sustainable learning effect and higher sensitizing to engineering technology from the students´ side.

The yearly course evaluation in the last years has shown that the course was considered rather “too theoretical” and “dry” by the students. Those comments are representative examples of the students´ opinion of the lecture and highlight the need for a reconstructing it. On the other hand, the “TUTOR system Garching” [10], a volunteer program based on student initiative, has been a positive example of students’ engagement in team work and innovative product development. The TUTOR system gives students a methodical and social qualification within workshops on topics, such as: group development and work in a team, communication, facilitation, presentation, learning techniques, time and self-management, working with targets.

The new concept for teaching the principles of engineering design is based on those two components: the course, providing fundamental technical knowledge and the team work, providing a praxis-oriented application of this knowledge. The new teaching concept has been developed by Professor Dr.-Ing. U. Lindemann and scientific assistants, who supervised the course, within workshops and discussions. The main objective of the new teaching concept is to enable students to understand the qualifications required in the development and production activities, and their context in the overall product development process. A development process from goal definition to concept execution is simulated within teams of 12-15 students. Thus, challenges of real developments projects become clear and students learn how to confront them. A further goal is, that students apply the lecture contents in their own projects. Development models, methods, as well as principles of engineering design should be applied by the students. Thus they are able to develop, analyse and evaluate solutions for development tasks. A design brief is given in the beginning of the semester, providing the student teams with an example for applying these contents. Dealing with a concrete product should motivate the students and enhance their engagement.

## 3 STRUCTURE OF THE LECTURE

The module consists of the course "Principles of Engineering Design and Production Systems" (i.e. lecture) and the processing of a development task in a student team (i.e. project). While the exam on the lecture’s theory is held as a written exam, the project results are assessed during an oral presentation about the group’s proceeding and the product developed.

### 3.1 Lecture

In the lecture, theoretical foundations for development of technical products are being taught. The lecture is offered by the Institute of Product development, being responsible for teaching the fundamentals of product development and organising the lecture, supported by three further institutes for production and manufacturing. Until 2012, content concerning product development and production systems was presented in the lecture in sequence. In 2013, the two theoretical parts of the lecture were offered in parallel, with the part concerning production beginning in the second half of the semester in five lectures on *Fundamentals of production technology and manufacturing*. Figure 2 depicts the theoretical contents of the lecture. The fields in *italics* represent the contents on production systems, which in 2013 have been offered separately.

The product development process is presented with focus on supporting the individual process steps. The Munich Procedural Model [11] is introduced as guideline for developing a product. Methods for abstract description and analysis of complex technical products are presented. In addition to the basic manufacturing processes, rules and principles for materials selection and structural design of technical products are introduced. Finally, construction procedures and the systematic influence on production costs are presented. The theoretical part of the course on product development consists of 12 weekly lectures of 90 minutes. The contents of the lecture are presented as PowerPoint slides, while real objects used as examples are shown during the lecture. The slides extended by explanatory text are published as teaching material.

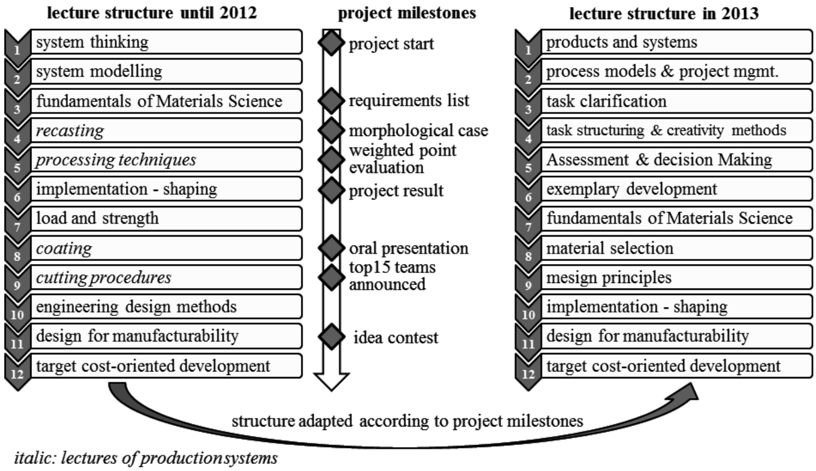



*Figure 2. Contents of the lecture "Principles of engineering design and production systems"*

#### *3.1.1 Written exam*

In the written exam, the knowledge of the taught content is assessed. Thus, the focus lies on the detailed knowledge of methods, manufacturing processes as well as the principles of materials selection and design methodology. The exam lasts 90-minutes and contains about 90 multiple-choice (type: single-choice) questions. As result the students are regularly graded and the received grade determines the grade for the whole module. In case the project part is passed, students who succeeded in the written exam receive 4 ECTS.

### 3.2 Project

In the project 10-15 students work for 7 weeks on a development task in teams applying the theoretical content in practice. The teams had worked together in the "TUTOR program" provided in the former (first) semester and thus obtain knowledge in soft skills (workshop topics are presented in 2.2). The results of the development project are assessed within an oral presentation, in which each student group presents their results on a DIN A0 poster. As the intended learning outcomes are the exemplary application of taught methods and the experiencing of a product development task, the main focus of the assessment lies on the application and learning effects instead of the achieved product quality. In the beginning of the semester, students are provided with a design brief, a template for the poster (Figure 2). On the poster, the methodological approach should be presented with the stated methods and their results to each of the following development phases: Task clarification (requirements list), solution search (morphological case and creativity method 6-3-5) and concept selection (weighted point evaluation). Particular attention is paid to: completeness, compliance with formal rules, proper application of methods, reflection of the methods application, useful application and reflection of the procedure (e.g. challenges, iterations), and overall impression.

#### *3.2.1 Oral exam*

In a 10-minute presentation the groups each have to present their developed idea and concept, integrate their proceeding into the Munich Procedure Model, present the application of four selected methods in detail and reflect and discuss their overall proceeding. The presentation is held orally, based on a poster according to the template in Figure 3. The students may split the presenter's role or choose a single presenter. Subsequently the group is interrogated and their knowledge and understanding of the methods is assessed by an oral questioning. Here the examiners are instructed to explicitly interrogate all group members. The main criteria of the assessment are the correct and expedient application of the methods and the understanding of these methods. Moreover the proceeding and reflection as well as the presentation are considered. All members of the group finally are graded “passed” or “not passed”. In the first project run in 2013 a jury simultaneously rated the creativity of the product idea, which built the base for a voluntary idea contest among the 15 top teams.

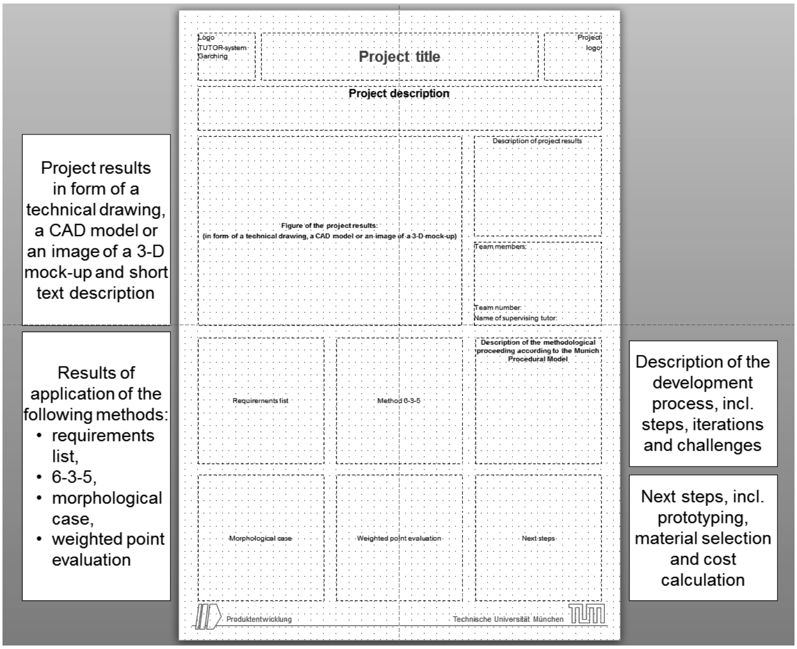



*Figure 3. Poster template for presentation of the project*

## 4 OBSERVATIONS AND FEEDBACK

During the first run of the course in 2013, revealing observations were made and feedback of participants, tutors and supervisors was collected, concerning 3 main issues:

### 4.1 Level of detail in task specification

The brief given to the project participant was the theme: “Back to nature: survival of the best equipped”. The topic has been defined by tutors organizing the idea contest and scientific assistants. The motivation for selecting a theme rather than a specific product was to enable the students to confront the challenges of task definition and task specification [11]. According to the participants this challenge was way too demanding and it took some groups up to 3 weeks to find the final product idea. Reflecting on this topic, the scientific assistants agreed that the time span of 7 weeks does not allow such an extensive task clarification and in future more specifications, like target group and product category will be predefined. The methods to be applied by the group will also be predefined in 2014, since many groups had difficulties in choosing the appropriate method.

### 4.2 Focus on the engineering process instead of product

After the oral presentations and the publication of the results many students were disappointed regarding the evaluation of their ideas. Obviously the students tend to focus on their product idea itself, while method application and expected learning outcomes move out of scope. Participants wanted to present their developed ideas instead of the methodological application. This explains their reaction, when they mainly are questioned on the methods and principles they applied. Yet, this notion shows, that one main aspect, the importance of methodology, is not completely understood by the students. In order to avoid an inhibition of the students’ creativity it is essential to reduce these negative impressions. Our approach for 2014 is to explicitly communicate the separation between product idea and application of the methods. Therefore the assessment of the product idea and creativity will be shifted to a separate event prior to the oral exam. Thus, we expect the students to realize the focus of the oral presentation and to reduce possible disappointment.

### 4.3 Organizational aspects

Many participants expressed the wish to get a clearer description of the expected results from the beginning of the project. The example shown in the sixth week helped, but came rather late. To improve this aspect, in 2014 the exemplary development will be shown in the second week and will be enriched with results from the projects in 2013. In every lecture, slides with examples and references to the project work will be added. In 2013 the supervision with regard to methodological application was on demand. Evaluation has shown that this was insufficient, since many teams applied methods incorrectly. Additionally weekly office hours will be provided during the whole duration of the project to provide better support to the young developers. Project duration has also been an issue for the students; therefore the project timeline will be extended by 2 weeks in 2014.

## 5 CONCLUSIONS

Applying the principles of project work, experiential learning and good practice in education [12], the course "Principles of Engineering Design and Production Systems" has been reconstructed. The learning effect and the sustainability of the lecture are increased due to practical application within an engineering project. Through the project work positive influence on future projects or the Bachelor Thesis is expected. Following participants', tutors' and supervisors' feedback, further improvements will be made: changes in lecture structure (order of courses), more specifications and clearer focus on methods, extension of project duration and weekly office hours. To reward assiduous project work the written exam will be extended by more transfer questions.

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# WASTE AS A STARTING POINT – HOW TO EDUCATE DESIGN STUDENTS TO BECOME ACTIVE AGENTS IN CLOSING MATERIAL LOOPS

**Isabel ORDOÑEZ, Oskar REXFELT and Ulrike RAHE**
Department for Product and Production Development, Chalmers University of Technology

**ABSTRACT**
The Waste to Design project gives students a framework to do their thesis on trying to use industrial waste for new production. The first year of the project saw four theses, shedding light on the design process required for this type of work. The most common difficulties observed were uncertainties about material properties, production possibilities and regulations. This made students strive to connect and collaborate with people from other backgrounds, suggesting that improving cross-disciplinary collaboration skills in design education would facilitate this type of work.

*Keywords: Industrial waste, design process, closed-loop*

## 1 INTRODUCTION

Design has an active role to play in helping society strive for a sustainable use of material resources. It has been suggested that this can be achieved by maintaining materials in closed loops. This means that instead of discarding a product after its use, it is sent back to be reused, refurbished or recycled [1]–[3]. This casts new light on discards, turning them into input for new production. When this is acknowledged while designing a product, developers can plan how to take back and reuse their material resources (e.g. Ricoh printers [4], Wilkhahn office furniture [5]). Unfortunately, most production is not being done in this manner, nor are the take back systems needed often in place, resulting in still increasing waste volumes worldwide [6].

Up until now design has not necessarily aimed at taking in waste in a systematic way. This is reflected on the fact that there is no methodology developed to facilitate designing with waste. The project "From Industrial Waste to Product Design" (W2D) is a first approach to investigate what methods can be useful for this task, while illustrating how this process is done. If a methodology can be developed it can be used in design education to give the next generation of designers better tools to actively engage in recovering discarded materials into society's material flows.

Even though designing with waste is not novel, there has been little documentation of the methods used to achieve attractive products from discarded materials. In order to be able to review the process of designing with waste closely, the W2D project presents this challenge as a theses topic for last years students of design programs. As a starting point the students have to use existing industrial waste (that is currently land filled or incinerated) for new product development. This poses a different setting for the design process. Normally, design starts from a specific product briefing to be fulfilled or a defined user need to be satisfied. In this case, the design process takes off from a material fraction out of which a wide array of products could be developed. Most of all, the project aims to investigate the challenges that arise with this different point of departure and to see what can be done to help designers in this task.

The W2D project has been running since fall 2012, and will be finalized in spring 2015 under the Mistra Closing the loop initiative [7]. It is collaboration between industrial recycling company Stena Recycling, engineering consultancy Semcon and Chalmers University of Technology. Design students are asked to do product development using one of the materials offered as main input for new production. The materials they can choose from are industrial discards that Stena Recycling receives that currently do not have a fully functional recycling market (e.g. PVC cable sleeving, PUR foam). The project gathers experts from industry (Semcon and Stena) and academy (from the design and material fields at Chalmers) to provide supervision time for the students that decide to get involved.

The first year saw the work of two bachelor and two master theses. This article collects the data gathered from reports, logs, interviews and the experience of supervising these students in order to highlight the lessons learned during the first year of the program. This knowledge will be used to better prepare the next group of students in the program, but also to shed light on what aspects become relevant for industrial design education when we expect designers to become active agents in closing material loops.

## 2 W2D PROJECT SET-UP

While preparing to receive the first group of students for the project, the authors investigated what methodology designers use when working with waste as a starting point. Even though several products made from waste were studied, no reference to methods or design processes was found. The examples of designs made from waste were studied further and categorized in a separate article [8].
Later, a review of the traditional design process was done in order to propose a process structure that could help designers to work with waste as input material. The proposed structure comes before the normal design process and is divided in three sections: research about the material, idea generation for application areas and a screening stage. This would result in a product idea that can be taken forward with a traditional design process [9]. A traditional design process was considered a funnel, where different stages of idea elaboration are followed by reduction of ideas, arriving after several iterations and levels of detail, to a finished product [10], [11]. This proposed process for designing with waste was presented in an article [9] that was shared with the students involved in the W2D project at the beginning of their thesis work. Figure 1 gives an overview of the process proposed.

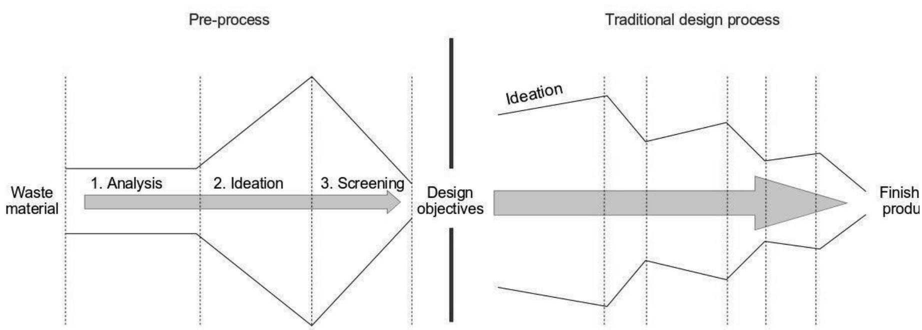


*Figure 1. Diagram of the proposed process for designing with waste*

The project contemplates three joint sessions with all the people involved for each semester the project runs. In a first Kick-off seminar, the project is introduced in detail and the different students meet each other and the people involved in the project from Semcon, Stena and Chalmers. Later, a mid term seminar and a final seminar are arranged for the students to present their work to the entire W2D group, allowing for fruitful and cross-disciplinary discussion.
Initially the W2D project was thought as a framework for Industrial Design Engineering (IDE) students to develop their master thesis. However, the call for thesis was promoted through the department's webpage, resulting in other students also showing interest to participate in the project. Despite that this was unexpected, the project accepted students with slightly different backgrounds: a couple of students from IDE, a couple of students from the Product Development (PD) masters and two pairs of bachelor students from the Design Engineering (DE) program. All students worked in pairs on their theses, so from the eight students involved, the project obtained four theses (two masters and two bachelors).

## 3 METHODS FOR DATA COLLECTION

To see how the students solved the challenges of the project, the authors were assigned as supervisors and/or examiners for the different theses. This allowed the authors to follow the process closely

through the **supervision session**, while not interfering with the students liberty to try methods on their own, since non of the authors had had any experience designing with waste previously.
Students were expected to deliver **weekly logs** about their progress. There was no template or structure for the logging, just that one to two pages should be submitted on Friday every week. This was done in order to have information about their progress and problems on a regular basis. After the students' work was finished, these logs were coded and summarized.
Students were addressed in **semi-structured interviews** after having finished their theses. This was done in order to get their personal reflection over their own process. They were asked to visualize their work process retrospectively using pre-prepared phase-markers for the different design stages (i.e. research, evaluation, creation). They could use as many as they wanted and were allowed to add extra information by using post-it notes.
All final **reports** were published via the Chalmers university library system, both in printed and digital format and are now publicly available through the library [12]–[15].

## 4 RESULTS

All theses done under the W2D framework resulted in projects that were approved at the end of the semester. Table 1 gives an overview of the projects done under the first year, while Figures 2 to 5 are images of the products proposed.

*Table 1. Project overview*

| **Student group** | **A** | **B** | **C** | **D** |
|---|---|---|---|---|
| **Academic Level** | Masters | | Bachelors | |
| **Program** | IDE[1] | PD[2] | DE[3] | DE |
| **Material used** | PVC cable sleeving | PUR foam | Divinycell[4] | PVC cable sleeving |
| **Type of waste** | Post consumer | Industrial waste | Industrial waste | Post consumer |
| **Proposed product** | Modular sound absorber | 4 concepts: Screen walls, cooling bags, lamps, play blocks | Vertical garden structures | Modular outdoor flooring |
| **Development stage** | Detailed concept | Initial concept | Initial concept | Detailed product |
| **Main focus** | Workshop methodology | Mapping PUR waste flows | Material properties | Product development |
| 1: Industrial Design Engineering. 2: Product Development. 3: Design Engineering. 4: Commercial name for a polymeric foam composed of a mix of polyuren and PVC. | | | | |

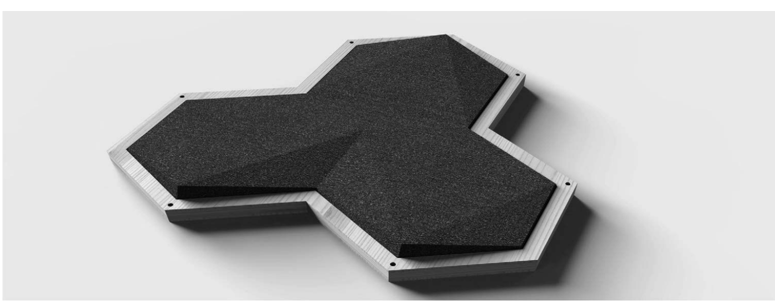

*Figure 2. Rekustik, modular sound absorber, of PVC cable sleeving, proposed by group A*

All students struggled with the lack of reliable information on the material, specifically concerning the properties and the potential production processes that could be used on the material in the form it was discarded. The four groups generated a large number of possible application ideas, which they later screened or categorized in different ways. All students, except group B, focused on one single application idea in the end that they developed further.

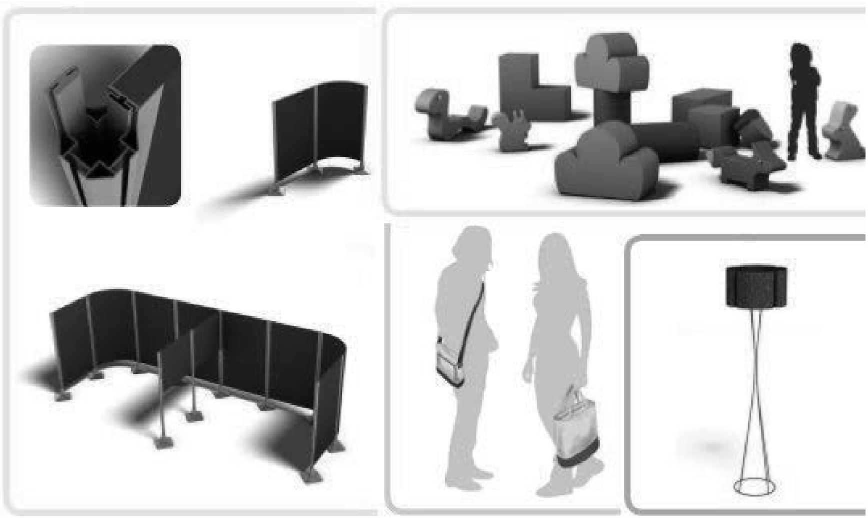

*Figure 3. Four concepts for using rebounded PUR foam proposed by group B. Clockwise: Large soft playing modules, lamp, cooling bags and screen walls*

Group B preferred to map possible application areas, exemplifying four of them with concept ideas that they had developed. The main results from group B were compiled and presented in a poster that maps the waste flows of polyurethane (PUR) foam. It shows the current recycling methods giving more detail to one of them (i.e. rebonded PUR foam), for which they mapped possible application areas that take advantage of specific material properties present in the recycled material. It can be said that they produced their work, in order to provide other designers with valuable information for using this material for future product development. Therefore, much time was spent on summarizing the material knowledge they gained into a simple, easy to understand format, which led to a convincing result.

*Figure 4. Vertical garden structures proposed by group C. Left to right: Image of pressed Divinycell sawdust board, vertical garden diagram*

For the groups that chose one product to take further, there was a “product selection stage” (as named by a student in the interview) that followed the idea generation. This was regarded as the most important phase of the work, spending several hours defining how to best make the right choice. Two groups reported that they spend much more time thinking of how to filter out ideas than actually filtering them out. They found it hard to find good arguments based on concrete facts about the materials' properties and production possibilities to support their decisions. At this stage they opted for using application areas that would not be problematic in any way and production techniques that they were familiar with, rather than proposing something that later would turn out to be unfeasible. Two groups consulted with material experts during this phase to make an informed decision.

All groups contacted material experts during their project. One group commented during the interview that they had expected to be able to ask a material expert all they needed to know about the material, so they could move straight on to product development work. However, they were unsatisfied with the answers they received, so they were forced to investigate the material further by themselves. In the end, the students found researching about the material mostly disorienting, especially given the fact that they often came up with contradictory information, forcing them to carefully examine their sources. Groups A, B and C contacted the experts mostly during the first half of the project (i.e. before the mid-term seminar), while they were focused on learning more about the waste material and its properties. Group D, also focused to learn most about the material in the first half of the project, but mainly building up on the material received from group A and their own literature study. As opposed to the other groups, group D contacted material experts mostly during the final stages of their work, in order to check with them the feasibility of the ideas they had developed, rather than to learn about the material.

## 5 CONCLUSIONS

The first year's work suggests that in order to support designing with waste, design education would benefit from preparing students for extensive multidisciplinary collaboration. This is needed since significant material knowledge is required, as well as good insight to the selected field of application (that can range widely).

The main barrier for developing products with current voluminous waste flows has shown to be the lack of reliable information about the discarded materials' properties. By the W2D students, this deficiency was experienced as the most challenging stage of the project. Material information is lacking because the producers of the discards are not involved in handling it and because the material properties may change significantly depending on the conditions it was used in. There is a definite need for material research to focus on discard flows as well as engineering virgin materials. Fortunately there is some research done in this line, and for the next semester of the project, students will be invited to work on a specific material that has already been studied and characterized in an ongoing PhD work at Chalmers University (i.e. mixed plastics obtained from electronic waste processing). Since the lack of material knowledge was reported to be so problematic for the first batch of students, for the next semester the authors will test a multidisciplinary student team, embracing one student with a product development background and one student from material engineering to complete the industrial design engineering knowledge.

*Figure 5. Återgångeng, modular outdoor flooring for events proposed by group D*

When trying to use waste material for new product development, all groups generated several ideas for possible application areas. This process was easy for the design students, who are used to applying methods that facilitate creativity and innovation. All students screened the ideas they generated in some way, during a product selection phase (new to the traditional design process). However, the study shows that good material knowledge is needed at this stage to help designers choose the best options for development.

Unfortunately, the material information that is lacking is not only needed to decide what to make out of the discards. It is also required to know how each material would perform in different application areas. Since this would be very difficult to evaluate for all possible application areas, it is suggested that some sort of material performance testing should be done after completing the product selection phase. Once a prototype with the material has been built, it should undergo the most relevant tests for the application it has been designed for. For example, in the case of the outdoor event flooring made of recycled PVC cable sleeving, a prototype should be exposed to UV radiation and undergo leakage and off gassing tests, to ensure that the use of that product would not emit unwanted chemical to the environment. Normally, this is not done in common product development, because manufacturers rely on their material providers' capacity of ensuring a given performance during a determined use phase. In the W2D case however, the material is obtained by the recycling industry, that cannot guarantee material quality standards.

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# NEW COMPETENCES REQUIRED IN FUTURE DEVELOPMENT OF DESIGN EDUCATION

**Nicola CREA**
Politecnico di Milano

**ABSTRACT**
Evolving from his early abilities of artist applied to improve industrial serial products, the designer should be able now to manage the whole process of innovation, from detection of user needs to new possible ways of product distribution. To perform these activities designers have to be prepared in different fields of knowledge. Time for this preparation might be too long for a course of studies in higher education. Starting from a list of qualities and competences that design professionals should perform, the research aims to identify which skills or abilities could be acquired earlier in the education path. What are the desirable qualities that a student should already have in terms of character disposition, specific technical knowledge, creative or speculative abilities, sensibility or taste refinement, entrepreneurship, or competence on specific issues? From a survey on a hypothetical "design professional profile", and trying to define a priority list of the different subjects to learn, supported by major pedagogical principles, the paper describes what a desirable evolution for a designer could be. Purpose is to give useful and verified information to teachers and institutions desiring to offer more complete and appropriate preparation to their students.

*Keywords: Design education, future, pedagogical principles, teaching, multidisciplinarity*

## 1 INTRODUCTION

*"In the creative arts, including design, the whole point of the business is to create something which other people will experience and which is in some way or other original and new"* (B. Lawson) [1] therefore different from what is ever been done before and different from what has been taught. Teachers have to teach methodology and tools for representation and communication of concepts and ideas without interfering with student creativity. A big effort is made to transfer design thinking and problem solving skills when students have little, if any, background on the subject. In order to make these tasks more easily reachable, it would be desirable that students could possess personal qualities, such as, for example: open mindedness, mental freedom, creativity, intuition, curiosity, analytical/critical attitude, strategy in complex situations, passion, emotional involvement, sensibility and perception. Many of these are considered as fruit of natural inclination or qualities of personal character. Common belief is that most of these cannot be taught, being part of individual natural predisposition; schools, in fact, very rarely give courses on these subjects. Nevertheless *"design is a form of thinking and thinking is a skill. Skills can be acquired and developed"* (B. Lawson). If there are no opportunities to learn or enhance these abilities systematically, how can the students individually grow and therefore improve their performances? Students at the beginning of their design studies are generally not properly prepared to acquire design thinking process in its articulations. They typically improve some of these characteristics during their studio practice of design projects. This happens without control, a consolidated practice and according to casual factors as school environment, type of project, attitude and quality of other students and the attention of teachers to these specific matters. Individual mental skills and intellectual values should probably be taken care of at early stages of education. To begin with and to understand what can be done practically, we must identify first which are the specific skills required, or at least desirable, to be developed.

## 2 REQUIRED SKILLS

*"First aspect to consider related to teaching, includes how to provide creative and innovative practices which stimulates the development of multiple intelligence, possibility thinking, and higher-level thinking, or how to involve the opportunity of exploring and solving problem"* (Yu-Sien Lin) [2].

J. P. Guilford [3] made several studies analyzing the structure of intelligence and peculiarities of creative thinking. In 1954 he published with R.C. Wilson, P.R. Christensen and D. J. Lewis, in Psychometrika a study titled “A factor-analytic study of creative-thinking abilities”, mentioning that “*in this study an attempt was made to isolate and define abilities in the domain of creative thinking, particularly as it applies to science, engineering, and invention*”. Eight main factors were identified as components of the mental elaboration implicit in creative thinking processes: Sensitivity to problems, Fluency, Flexibility, Originality, Penetration, Analysis, Synthesis and Redefinition.

| References / Mind Functions | **GUILFORD** *Factors of creative thinking* | **GARDNER** *Five minds for the future* | **DE BONO** *Six thinking hats* | **JAOUI** *P.A.P.S.A.* |
|---|---|---|---|---|
| **EMOTIONS** **Emotional impact** **Personal implication** | Sensitivity to problems | Ethical mind | Red - Emotions | Perception |
| **CREATIVITY** **Research** **Production of ideas** | Fluency Flexibility Originality | Creative mind | Green - Creativity | Analysis |
| **LOGIC AND THOUGHT** **Rational approach** **Search for solutions** | Penetration | Disciplined mind | White - Objectivity Yellow - Optimism | Production |
| **CRITICAL APPROACH** **Deal with problems** **Elaboration process** | Analysis Synthesis | Synthetic mind | Black - Criticism | Selection |
| **APPLICATION/EXECUTION** **Deal with others** **Relationship with contest** | Redefinition | Respectful mind | Blue - Management | Application |

*Figure 1. Comparison of identified factors in design thinking*

H. E. Gardner, developmental psychologist at Harvard University, best known for his Theory of Multiple intelligences, has analyzed deficiencies of our present educational system. In his publication *Five minds for the future* [4], he argues that teaching is not synchronized with the pupils education needs. He says that the amount of knowledge to acquire is so wide that it is impractical to teach all its necessary and that the constant change of technologies, knowledge and vision of the world makes school teaching obsolete. He believes that we should overcome the present division in disciplines for a multidisciplinary view of knowledge. To face these issues we should establish a system of permanent education, define what are the essential competences to acquire along intellectual development and understand what would be the appropriate timing for a coherent evolution process. Gardner proposes five forms of intelligence to develop in order to answer to the outlined deficiencies: *a disciplined mind*, to analyze different approaches to an issue, to learn the ability to define priorities and to catch relevant concepts; *a synthesizing mind*, able to select information and knowledge, to think within an interdisciplinary framework, perceive the essential of things, identify strategies; *a creative mind*, to develop personal sensitivity, identify a personal path and the will to explore; *a respectful mind*, to understand multi-culture, flexibility of context, complexity of mind and human inter-relations; *an ethical mind*, to learn to share, to approach common causes with integration of competences and to work in the common interest. For more accuracy in the search of personal qualities to develop, it is appropriate to analyze what are the major elements of the design thinking process for E. De Bono [5]. He isolated the different components of the process in his tool *Six thinking hats*. Designing or searching to solve a problem, we deal with thinking categories that can be synthesized in six major types: emotional, creative, objective, positive, critical and managerial. These factors combined make possible the design or problem solving process. Each category, however, needs a specific competence and personal qualities behind it. Before any emotional implication there are sensibility and sensitivity. Open mind pre-disposition and free thinking attitude support creative processes. A disciplined and logic mind produces objective thinking. A critical spirit is necessary to evaluate negative aspects of things and management abilities are essential to plan, schedule, organise project activities and strategies. Components of design thinking, functional to the construction of our map, can also be recognized in the tool (*P.A.P.S.A.*) developed by H. Jaoui [6]. From this comparison chart [Fig.1] common elements can be identified, even if named differently. Once assumed that these are reliable categories of thinking integrated in the design process, we need to identify what would be the appropriate time and mode to grow and refine each of them, along the individual evolutionary process.

## 3 PEDAGOGICAL ORIENTATIONS

To define this properly it is necessary to compare the most widely recognized pedagogical theories that emphasize the growth of creativity and freedom of mind and analyze the findings. Development of individuals is a delicate process that includes physical, spiritual and intellectual aspects. In the last hundred and fifty years pedagogy has provided several experiences in this direction that are definitely worth to consider. Along with J. Dewey's attention for democracy and experience in education, R. Steiner, E. Claparède, and K. Fischer, gave a decisive contribution in understanding the articulation of the learning process. "*The developmental psychologists such as Bruner and Piaget have shown how human thought processes develop in parallel with the child's formation of such basic and fundamental schemata"* (B. Lawson). R. Steiner [7] is renown as the founder the Waldorf pedagogy, educational theory based on anthroposophical principles. Schools applying Waldorf pedagogy are now spread throughout the world and cover educational need from pre-kindergarten up to eighteen years[1]. According to Steiner intention, pedagogy must be defined directly by the necessities of evolving child, and not according to objectives such as economic productivity and professional qualification. Steiner's conception of the needs of the child is based on his anthropological observations, including, the tripartite division of man into body, soul and spirit (will, feeling and thought). From this derives the ideal of harmonious education of the cognitive-intellectual faculties (thinking), creative and artistic faculties (feeling) and handy-crafts faculties (will). Result is a wider educational context for arts and crafts, not primarily driven by the typical cognitive-intellectual learning. Along with R. Steiner, M. Montessori and L. Malaguzzi gave a decisive contribution to free-thinking and care for potentials of personal development on children education. M. Montessori [8][9] identifies children as complete beings, able to develop creative energies and possessors of moral dispositions (such as love), that the adult has compressed inwardly making them inactive. Basic principle is mental freedom, since only this encourages creativity already present in child's nature. To M. Montessori a disciplined individual is able to regulate himself to follow the rules of life when it is necessary. Childhood is a period of enormous creativity, the child absorbs the characteristics of the environment growing naturally and spontaneously without to perform any cognitive effort. The child is a spiritual embryo in which psychic development is associated with biological development. L. Malaguzzi [10] is founder and promoter of *Reggio children*, school coherent with the process of self-actualization of individuals. L. Malaguzzi firmly believes that what children learn is not a directly linked to the teaching processes, but that the largest part of the work is done by children themselves, their activities and the use of available resources. Children always play an active role in the construction and acquisition of knowledge and understanding. Learning is seen as a self-constructive process. In the schools of L. Malaguzzi there is a close attention to the aesthetic sense as there is a belief that there is also an aesthetics of knowledge. He said, *"..the kids build their own intelligence. Adults need to provide them with the organization and the context and especially they have to be able to listen"*. E. Claparède [11][12] after studying various aspects of the infantile psyche, argues that the child, who is not an imperfect adult, has a perfect and autonomous mentality in himself for each development phase. Its development follows specific stages and the game is a functional exercise preparatory to develop their cognitive and affective abilities. According to his studies, children go through 3 stages that enclose 6 Fundamental Evolutionary steps. These follow 6 laws of functional development upon which he founded his teaching pedagogy, called *The Pedagogy of Interest* where teachers are stimulators of interest and organizers of learning situations. The laws of functional development are: genetic inheritance; functional exercise; exercise genetic; functional adaptation; functional autonomy and individuality. The 3 Fundamental Stages, that form the basis of the study of the educational-

[1] note: According to sources of June 2009 there are 994 Waldorf schools worldwide of which 681 in Europe.

evolutionary-functional theory of individuals, are: The first *Stage of purchase and experiment* that contains the first four evolutionary periods covered by the interests of the child: Perceptual (1 year old); Language (1-2 years of age); General and why (3-7 years old); Special and objectives (7-12 years old). The second *Stage of order and evaluation* that contains the fifth period which is characterized by those interests: Sentimental, Ethical, Social, Specific, Sex (12-18 years of age and older). Finally, the third *Stage of production* contains the sixth developmental period marked by interest: Job (18 onwards adulthood). J. Piaget [13] from his studies on cognitive development and evolutionary age, observed differences in approaching problems according to age. He was able to identify and isolate four basic stages of cognitive development, common to all individuals, and that are always followed in the same sequence. The four distinct stages of his theory about intellectual development include: *Sensorimotor Stage* (0-2 years), the child goes to the radical egocentrism in object representation and symbolization using patterns of action. He acquires the sense of object permanence understanding it as pre-existing entities, external to himself. *Preoperational Stage* (2-6/7 years) the child begins to use symbols and context reasoning. He is transductive, makes associations without logical connections and remains the intellectual self-centeredness. *Concrete operational Stage* (6/7-9/10 years), the child uses symbols and manipulates them by following logical operations. *Formal operational Stage* (12 years old and over), the child completes the cognitive development; he begins to formulate abstract thoughts, far from reality and experience, using the *hypothetical-deductive* thought, demonstrating possession of the same thought patterns of an adult. J. Bruner [14] made detailed studies on the cognitive process and draw conclusions similar to those drawn by Piaget. The major difference is that, J. Bruner has not associated the stages of development with chronological age. The developmental stages are described in terms of nature of the experiences used by an individual to form concepts. According to J. Bruner intellectual ability evolve, as a result of maturation, training and experience, in three stages: *enactive stage, iconic stage and symbolic stage*. In the Enactive stage cognitive experiences are captured and represented through motor activities and physical action. The child knows the world only through actions, not through words or images. The infant understands his environment by touching, biting and grasping, accordingly to the Sensori-motor stage of J. Piaget. The Iconic stage is characterized by the child's representation of things and events in terms of sensory images or mental pictures or icons of perceptual experiences. Information is gained by imagery and the cognitive process is controlled by perception. Child is attracted by single features of the environment. During the Symbolic stage, cognitive experiences are received and represented through symbols. The child engages in symbolic activities, such as language and mathematics. Actions and images are translated into words. The symbolic stage allows experiences condensation into formulas and into language and semantics.

<table>
<tr><td>GROWTH PHASES</td><td colspan="11">CHILDHOOD</td><td colspan="13">ADOLESCENCE</td><td colspan="4">ADULHOOD</td></tr>
<tr><td>EDUCATION FRAMEWORK</td><td colspan="3">NURSERY</td><td colspan="3">NURSERY SCHOOL</td><td colspan="5">PRIMARY SCHOOL</td><td colspan="3">JUNIOR HIGH-SCHOOL</td><td colspan="5">HIGH-SCHOOL COLLEGE</td><td colspan="5">UNIVERSITY</td><td colspan="4">SPECIALIZATION PROFESSION</td></tr>
<tr><td>AGE</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>…</td></tr>
<tr><td>MARIA MONTESSORI</td><td colspan="6">CHARACTER DEVELOPMENT</td><td colspan="5">SELF-AWARENESS GOOD/BAD PERCEPTION</td><td colspan="7">SOCIAL AND MORAL-AWARENESS FEELINGS</td><td colspan="10">…</td></tr>
<tr><td>JEAN PIAGET</td><td colspan="2">SENSORI -MOTOR STAGE</td><td colspan="4">PRE-OPERATIONAL STAGE</td><td colspan="5">CONCRETE OPERATIONAL STAGE</td><td colspan="17">FORMAL OPERATIONAL STAGE</td></tr>
<tr><td rowspan="2">EDUARD CLAPARÈDE</td><td colspan="12">STAGE OF PURCHASE AND EXPERIMENT</td><td colspan="6">STAGE OF ORDER AND EVALUATION</td><td colspan="10">PRODUCTION STAGE</td></tr>
<tr><td>P*</td><td>L*</td><td colspan="5">GENERAL INTERESTS AND «WHY»</td><td colspan="5">SPECIALS AND OJECTIVE INTERESTS</td><td colspan="6">SENTIMENTAL, ETHICAL, SOCIAL, SPECIFIC, SESSUAL INTERESTS</td><td colspan="10">WORK INTERESTS</td></tr>
<tr><td>KURT FISHER</td><td colspan="11">ELEMENTARY EMOTIONAL STAGES</td><td colspan="17">ABSTRACT THINKING<br>CRITICISM, OPPOSITION AND REFUSAL – SELF AWARENESS – DRAMATIZATION – ABSOLUTIZATION - ELABORATION</td></tr>
<tr><td>JEROME BRUNER</td><td colspan="28">ENACTIVE STAGE ICONIC STAGE SYMBOLIC STAGE</td></tr>
</table>

*Notes:* **P*=** *Perceptive interests* **L*=** *Languages interests*

*Figure 2. Identification and comparison of major developmental stages in pedagogy*

## 4 CROSSING DATAS

Evaluating the map [Fig. 2] we notice that all the selected authors describe children to be the centre of the education process and they respect, except for J. Bruner, their timing of development. The map shows consistency among various orientations and that discrepancies are negligible. Different evolutionary periods describe cognitive peculiarities for each age of growth. Further advancement is done matching the desirable intellectual and mental qualities outlined in Fig. 1 with the most appropriate time for development using Fig. 2 findings. To identify the correct evolution period we have to clearly understand how receptive are and to what kind of process learners go through. From Fig. 2 shows that design thinking process have roots at the very early stages of human development and that some mind attitudes and thinking qualities can be acquired right at the beginning of the education process. Emotional qualities are the first to be developed, right after birth (K. Fisher) [15]. For the first three years we go through an unconscious process of development where emotions start their building process. In the next three years we start developing language, active experience and will. Through play children develop creativity, fantasy and imagination. To see the beginning of logical and disciplined thought we have to wait the age of six. With adolescence, around twelve years old, kids typically develop a strong critical attitude that, if positively channelled, could set the bases for structuring critical thinking. With maturity, at around eighteen years of age, an individual should have completed his path to build abilities of evaluation and synthesis. Right after he could be ready for proposition of new ideas using logic-deductive thinking, imagination and symbolism (use of code languages as in music, mathematics, etc.). The map [Fig. 3], resulting from the crossing of Fig.1 and Fig. 2 data, shows the coherence between the qualities to acquire and the receptive potentials of individuals in each development phase.

## 5 PREVIOUS EXPERIENCE AND CONCLUSIONS

Many models have been offered to set educational objectives, but maybe none has been more influential than *Bloom's Taxonomy of Educational Objectives* (B. S. Bloom, et al 1956) [16]. *The Cognitive, Affective and Psychomotor Domains of Learning* defined by Bloom and his colleagues has been interpreted and applied as model of design thinking in order to define the educational objectives associated with each dimension of the model. In 1990 C. Burnette a design educator, initiated the *Design Based Education K-12 Program* at the University of the Arts in Philadelphia with J. Norman**.** He developed the I DeSiGN educational theory finalized to the diffusion of the design thinking skills among children in early years of their education. He identified and analyzed the components of the design thinking process following Bloom's principles of taxonomy and reviewed by L. Anderson and D. Krathwohl [17], who modified the original structure according to which the majority of skills can be acquired and used simultaneously or in any order. *"This is different from the old taxonomy, which stated, for example, that you cannot apply if you don't understand, or that you must understand before you can analyze,"* Anderson explains, *"We know now that in many cases, these processes can be learned simultaneously, or even in reverse order".* Four levels of progressive learning experiences were suggested for teaching design thinking: level 1, learning individual ways of thinking; level 2, learning how all modes of thinking work together; level 3, learning to apply all modes of thinking; level 4, learning through personal application of the modes of thinking. These levels suggest how a child should progress as they learn to use the I DeSiGN model and indicate the kind of structure and content they encounter at each level. "*A curriculum design should expect children 3-4 years old to focus on levels 1 and 2; children 5-6 years old on levels 2 and 3, and children 7-8 years old on levels 3 and 4. However, children should be able to progress through the levels as rapidly as their capabilities permit*". This indication nevertheless leaves out some of the newly identified skills to acquire, it doesn't match timely the natural qualities development and it needs to adapt to the receptivity and the relative maturity levels of the learners. In conclusion, we can say that the aim of this study is to focus on the new competences required by the practice of design thinking and on the most appropriate way to transfer them to the students. The study identifies qualities and skills in areas of knowledge mostly neglected by traditional education, usually left to autonomous and random individual learning. It proposes a first form of integration [Fig. 3] of these new educational objectives synchronized with the timing of natural development of child's mind. If the goal to pursue is to form effective quality thinkers, problem solvers and designers, in the widest sense of the term, innovative pedagogical methods must be developed by multidisciplinary teams where design thinking competences are integrated by psychologist, pedagogues and experts in the field of education.

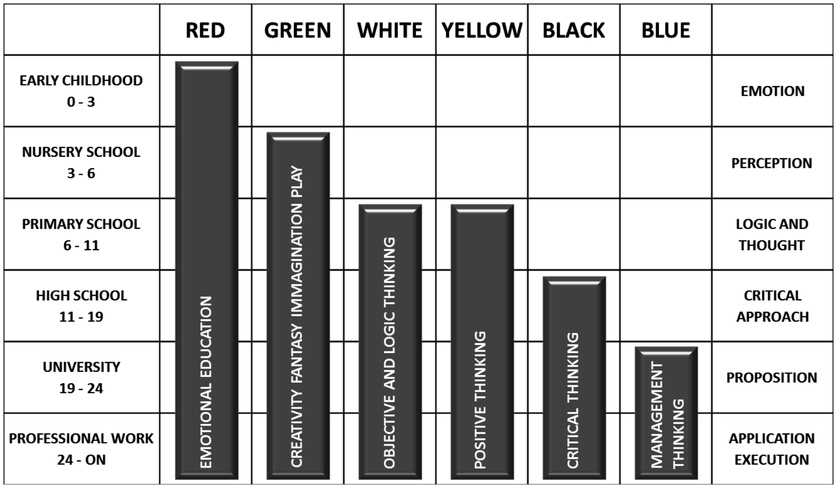


*Figure 3. Most appropriate timing for development of design thinking skills.*

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# 1 SHADE OF GREY; SIMPLIFY TO EXCEL IN SKETCHING FOR INDUSTRIAL DESIGN ENGINEERS

**John Daniel ÖHRLING and Bengt HOLMQVIST**
Division of Business Administration, Technology and Social Sciences, Luleå University of Technology

**ABSTRACT**
Sketching is a fast way to explore or communicate ideas and can be done instantly with almost no planning. Sketches are quick, dynamic and iterative. They can be made in many ways but are traditionally created by using pen and paper. This is one of the most efficient tools to trigger the creative process and keep it going. In the educational context where sketching and artistic skills are a compromise between traditional engineering and traditional Design education some problems can be identified. At the Industrial Design engineering program at Lulea University of Technology (LTU) the students are accepted on their grades only, and students attending sketch classes at LTU come from a wide range of backgrounds. As a result of this the sketching education must be tailored for students ranging from experienced level to inexperienced. When there are a lot of students and time is limited, learning activities must be implemented according to this reality. A way to speed up the learning process is to reduce the cognitive load. Too many possibilities and factors confuse students that are inexperienced in the field. The activities should also help keeping the rate of practice up and eliminate things that are not part of the intended learning outcome. This paper shows how a simple change of tools in the sketching class makes huge impact on the progress and discusses the mechanisms behind the effect.

*Keywords: Mechanical, engineer, creativity, sketching, design*

## 1 INTRODUCTION

The role of the sketch in creative activities is well established. Designers and architects have accepted that sketching facilitates creativity and have strong communicative qualities for representing thoughts and ideas. Catching the ambiguity in the design process [1], creating freedom of interpretation to stimulate creativity [2] and facilitating the design process in design groups [3] are some of the important qualities of sketching activities. Most important: Along with counting and speaking, sketching is a primary form of cognition and fundamental to human action [4].

This is important in all Industrial Design Engineering programs, just as for the Industrial Design Engineering program at LTU. What is typical for the sketching education at this program is that the individual prerequisites and talent among students varies within a wide range, and the education must be adapted to this situation. Courses with this mixture must start at a very low level to secure that everyone understands and have chance to improve their skills. As courses are relatively short this is a contradiction since starting from the very beginning is time consuming. Making good progress when time is short is a big challenge.

The experience from teachers is that inexperienced students are afraid of sketching. They want to draw perfect lines from the very beginning, which is difficult. This can be an effect of what Constable [5] calls the “pretty picture syndrome”, meaning that sketches are regarded as a final outcome instead of a tool for design thinking. This put focus on the performance of a sketch instead of the message.

Because of this anxiety it’s common that students draw a line, erase it and then draw the same line again. This eternal drawing-rubbing-drawing process can go on for hours with very little result to show when class is finished. They also spend a lot of time on soft shading and rubbing in the gradients on their precious drawings and sketches. Since they spend so much time on each sketch the progress is slow, and number of iterations is low. This flattens the improvement curve in relation to the duration of a course.

According to Buxton [6] a good sketch is quick, inexpensive, disposable, plentiful, has a clear vocabulary, minimal detail, appropriate degree of refinement, it suggests and explores rather than confirms and contains some degree of ambiguity. The stigmatizing notion that every line must be perfect doesn't fit into this description. It's the combination of more or less perfect lines that is interesting, the message. The intended learning outcome of the courses is not that the students will become artists, they are supposed to learn the language of sketching, improve their skills and use it as a tool for creativity. Just getting the lines right could be categorized into the lower orders of the SOLO-taxonomy (Structure of the Observed Learning Outcome, defined by Biggs & Collins [7]), but a Good sketch, because of its nature, is a result of the extended abstract level. So the sketch, as it is described by Buxton, is a simple structure, but the administration of it requires a high level of abstraction. To get there, the need to reduce the extraneous cognitive load [8] to facilitate learning is obvious. Not only in the presentation of the tasks, but also in the affordances of the materials that the students are confronted with.

The problems raised a question: Is the possibilities of the pencil actually hindering the progress in learning for inexperienced sketchers?

This paper reports the results of tests that was performed to see if providing tools that are permanent and only had one value could lead to a faster learning process, compared to using versatile and erasable tools like pencils. A group of engineering students and non-students for reference was to perform a simple still life tasks in two different setups. Half of them were equipped with pencils and the other one with black markers. The time to satisfaction was measured.

The study addresses two main assumptions about how to speed up the process and put focus on the essence of activities in sketching education: Beginners should have as few variables as possible to handle to reduce the cognitive load. By spending less time on each sketch there will be time to increase the rate of iteration and generate a steeper improvement curve.

## 2 METHOD

This section contains the background for the studies and a description of them, and ends with the results.

### 2.1 Background

In the program IDE (Industrial Design Engineering) at LTU there is a long tradition of teaching students sketching skills to strengthen the creative process in project assignments, creative workshops and presentations. In these program courses students come from varying backgrounds and with varying skills. The students apply for the programs on their grades and there is no demand on artistic skills to be accepted. This means that the level of talent and experience of drawing varies, and the learning activities must meet the needs of the most inexperienced. Taking an ordinary program sketching course means students have 30 hours of scheduled sketching and 170 hours to sketch on their own. This is not much time for learning activities when you have to start from a very basic level.

One thing that teachers have noticed is that inexperienced students are afraid of making inexact lines when sketching, and they worry about the artistic qualities of their work. Their focus is not on understanding how to represent the objects they draw and the signs they make, they are mostly focused on not drawing wrong. This idea of perfection, the pretty picture syndrome, slows the pace of the production down, and lowers the number of exercises and iterations that a student performs during a course.

To see the effect that the affordances of the tools used had on the performances of tasks and the learning process, experiments was conducted with students from different programs and also with staff employees of the University. Two tests were made; one intervention study where the performance was monitored during an ordinary class and one user study where the subjects were tested individually to verify the findings from the first test.

### 2.2 Test 1

The first test was an intervention study that was performed in larger groups with 20-25 students each. These students worked with an assignment that has been used for many years both at the courses at LTU and also at art schools in the region. This early-in-the-course-assignment is a measuring assignment to present basic knowledge about drawing by using measuring to depict real life objects, in this case a typical cardboard box about 50x40x80 cm of size. Students form a circle around the object

and teachers introduce the measuring technique. While student work with the assignment they can ask for help and teachers also offer guidance when students have got the instruction all wrong.
The same test was done with four parallel groups. Students in this case were freshmen at two different programs, Industrial Design Engineering and Engineering Architecture. For each class, one group used pencils and the other group markers. Time was measured from the point when everyone said they understood the instructions until the whole group had fulfilled the assignment. The teacher made sure that all drawings had acceptable perspective, lighting and shadowing.
To see if there could be a difference doing the same test with LTU staff members, two groups from the administration were formed with 6 subjects in each group. Compared to the student groups the staff members consisted of people with more diverse backgrounds, ages and interests.

### 2.3 Test 2

In this user study 20 students was instructed to draw two objects on a round table with light and shadow. Their task was to draw the objects until they were satisfied with the result. Different from the first test there were no quality check from the teachers since the focus was on the time subjects spent on the assignment on their own, the time a task was awarded without outer restrictions. This addresses the assumption that a higher rate of iteration will generate a steeper improvement curve.
Time was taken individually from when they started and until they claimed to be finished, and no guidance was allowed during the test. This was repeated with students from different programs with varying experience and interest of drawing. Half of the students used markers to draw the objects and the other half used pencils and erasers.
A time limit, that the subjects wasn't informed about in advance, was set to 60 minutes for two reasons: First of all to adapt it to a class situation where more time than this can't be allocated for a single task, secondly because it's 3 times the calculated time a task like this is supposed to take. This decision could affect the results if the time limit proves to be too short.

### 2.4 Result

***Test 1:***

The results from the first test setup (Table 1.) showed that test groups using pencils used a lot more time to produce an acceptable assignment. They needed 45-60 minutes to fulfil the assignment, and the groups using markers needed not more than 30-35 minutes to do the same job. A few subjects in the marker groups were faster than this but no one in the pencil groups finished their assignments faster than 40 minutes. Some subjects in the pencil group needed more than 60 minutes. The difference between the groups of students compared to the staff members was negligibly.

*Table 1. Result Test 1. Time for assignment in minutes*

| | 1st group | 2nd group | Staff | Mean |
|---|---|---|---|---|
| Pencil | 44 | 60 | 51 | 51,7 |
| Marker | 32 | 29 | 33 | 31,3 |

The results indicated that there were obvious differences in performance between the groups, but the data is too limited and uncertain to draw any direct conclusions from. Studying groups of 20-25 people and also having to help students by answering questions makes it hard to control the study. Some students might keep on drawing even though the result is satisfying, and it is also somewhat complicated to measure an accurate time with that amount of students. Since no regard was taken regarding outliers the measurement was a bit rough, but still it gave good enough indications to continue with the second test.

***Test 2:***

The result of the second test setup is visualized in Figure 1. On average, participants using marker (M=17.1 min, SE=3.69 min) completed the task faster than participants using pencil (M=43.1 min, SE=16.9 min). As the variances for the two groups differed, a t-test not assuming equal variances was used to test if the difference in completion time was statistically significant ($p<.05$). The difference was significant, $t(9.85)=4.73$, $p=.001$.

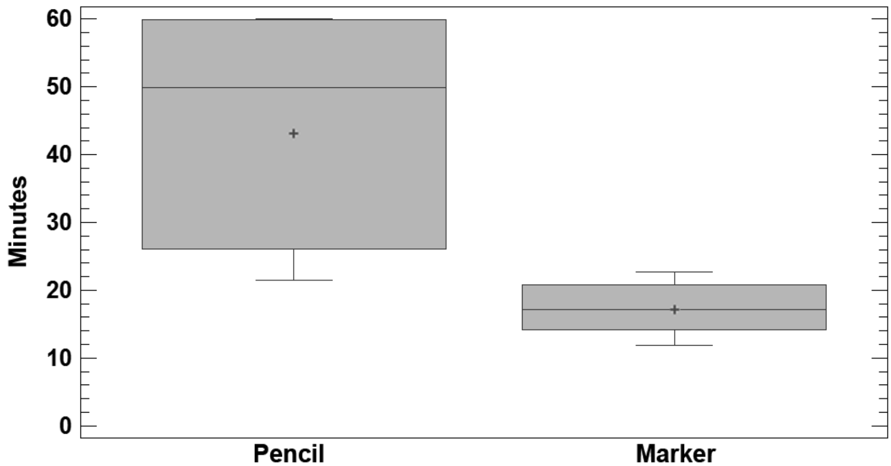


*Figure 1. Box-and-Whisker Plot of results from Test 2. The median is marked as a horizontal line within the box, the box shows the sample interquartile range and the whiskers show max and min values. The average value is shown as a plus sign. No outliers (deviating more than 1.5 times the interquartile range from the median) were observed*

In the pencil group two subjects could not finish their assignments within 60 minutes. The cut-off caps the result for the pencil group slightly, but if the full range had been measured it would have increased the difference.

In the marker group most subjects ended up in a very short span between 15-20 minutes while the pencil group is much more spread between 25-60 minutes.

## 3 DISCUSSION

The results, especially from Test 2, are very convincing: The study shows that a change of tools in classes with inexperienced students is a way forward when it comes to speeding up the learning activities. Speeding up the process will free up time, which is of great importance, especially when the time available is limited. Inexperienced students need to repeat training to improve skill. Drawing is mainly a handicraft and learning is very much about repeat and practice. The more time students have the more sketches they can produce, and this is important for the creative process.

An interesting behaviour can be seen in the range of results for the pencil and marker groups. Looking at the boxes for the sample interquartile range in Figure 1 we can see that the marker group ended up in a short span while the pencil group is much more widely spread. Our theory is that this is because the pencil with its versatility gives more room for individual excessive exploration. The marker is more "straight forward", when a spot on the paper is filled it's filled, and you move on. The similar time of completion is interesting and might indicate a pattern of how the subjects performed the task.

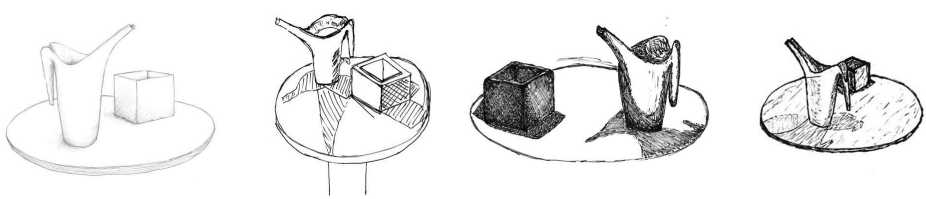

*Figure 2* *Figure 3* *Figure 4* *Figure 5*

Another important insight that the method generated was that non-erasable tools makes it easier for teachers to guide and explain how students should do and think to achieve a good result because it is easier to see what a student have done or not done when no lines are erased. The vagueness in Figure 2 illustrates this problem. The lines are hard to see and no hints of the working process. Figure 3, 4 and

5 show drawings made of subjects with the same estimated experience level as in Figure 2. Marker drawers need less than half the time to present an acceptable drawing with more information.

This does not mean that pencils are useless. Of course there are many advantages with using pencils and the versatility the medium offers. Still the conclusion of this study is that students in programs where the artistic skills are of less importance than traditional art classes can have an important advantage if pencils are avoided.

A question that is not fully answered in this study is if marker drawings will provide a better learning outcome. We see that there is a need for further studies to see the full implications of the result. First of all, qualitative studies regarding the mechanisms for the result and the cognitive operations that take place. From this study we can't see if the learning happens at the unistructural or extended abstract level. There's also a need for a study of long term effects to see how the improvement curve is affected by the choice of tools, and if there's a level of experience where limiting the possibilities also limits progress.

So what are the reasons for the results? Our theory is that the main reason is the difference in cognitive load. Less options means less factors to be distracted by. When only having one value to work with, it's easier to focus on the task instead of the details of the drawing. A comparison between the sample interquartile ranges for the different tools supports this. Another part of it can be related to the "pretty picture syndrome", the subjects lowers their expectations on their work and get a relaxed attitude to the outcome. Also there's a process change happening when the ability to erase is removed. Instead of erasing and redoing a misplaced line, a new one is drawn with the first one as reference. This strategy is more efficient and the workflow isn't interrupted. In the words of Sandy Brooke [9]: *"Since you can't erase, you will find a certain freedom in knowing that you are going forward ... When you stop to correct lines, you can lose your train of thought".*

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
4 & 5 SEPTEMBER 2014, UNIVERSITY OF TWENTE, THE NETHERLANDS

# TEACHING DESIGN ENGINEERING IN AN INTERDISCIPLINARY PROGRAMME

**Wessel WITS, Jasper HOMMINGA, Maaike ENDEDIJK, Klaasjan VISSCHER, Leonie KRAB-HÜSKEN, Frank VAN DEN BERG and Pascal WILHELM**
ATLAS University College, University of Twente, Enschede, The Netherlands

**ABSTRACT**
ATLAS, the Academy of Technology and Liberal Arts & Sciences, is an interdisciplinary three-year Bachelor of Science honours programme for talented students that opened its doors in September 2013. This international programme uses the concept of project-led education to teach students to integrate both technical and social perspectives into a new engineering approach. It aims to educate the so-called 'new engineer': a generalist who can combine technological and societal approaches with design solutions that can be implemented in a range of technical, social, and cultural contexts.
The programme has a thematic structure, in which a large project is the foundation of every semester. At the start of the semester the students write their own personal development plan framed by three domains (Engineering, Mathematics and Social Sciences) and six learning lines (Research, Design, Organization, Communication, Learning Capacity and Interdisciplinarity). In an interdisciplinary programme like ATLAS students have to learn to use knowledge from different disciplines and integrate it. This is also demanded by the project description, which is always a complex open-ended interdisciplinary problem. Design models from both engineering and social sciences are combined to develop new solutions for boundary-crossing problems.
In this paper we will describe the programme and its underlying educational principles in detail. We will show the interdisciplinary design-engineering model that we use in our programme. We will reflect upon our first experiences with the programme and define a set of challenges for teaching design engineering in an interdisciplinary programme.

*Keywords: New engineer, engineering education, design education, interdisciplinary design methodology*

## 1 INTRODUCTION

The call for a new engineer – a broadly educated engineer who is engaged with complex societal problems and has the technical and social competences necessary to work on solving these problems – is often heard in the academic world and in practice [1]. The Academy of Technology and Liberal Arts & Sciences (ATLAS) at the University of Twente is a university college Bachelor of Science programme that aims to educate these new engineers. The mission of ATLAS is 'to provide optimal learning opportunities for advancement in technology and liberal arts & sciences for the personal benefits of talented and ambitious students, who value interdisciplinarity and international perspectives on societal issues'.
University colleges in the Netherlands generally adhere to a liberal arts type of bachelor education as established in the USA. Classes are typically small with a high teacher-student ratio. In general, Dutch universities are prohibited from selecting students for their (bachelor) programmes and therefore have to accept any eligible high school student. For university colleges this is different. They are selective, taking in only ambitious top students with a broad interest. Currently, there are eight university colleges in the Netherlands [2]. ATLAS, being the first with an engineering approach, started in September 2013 as a residential college, where students live and study on campus in an enriching learning environment. The focus of the programme is not (just) one subject, but rather a broad education, preparing students not only with a sound academic foundation but also with essential professional competences.
ATLAS targets very talented, broadly interested students. However, what makes it unique is its focus on technology and its use of interdisciplinary Project-Led Education (PLE). Because of the distinct

purpose, the programme was designed as a radical educational innovation, inspired by other programmes at the University of Twente and other institutions (such as Utrecht University College in the Netherlands, Olin College in the USA and Aalborg University in Denmark), but did not copy existing templates. Central in this process were multi-disciplinary teams, a programme council and a curriculum development group in the preparatory phases, and a core team of lecturers for the actual development and implementation. The broadness and ambitious nature of ATLAS is also reflected by this core team. The lecturers come from different disciplines, in particular mechanical engineering, biomedical engineering, physics, mathematics, philosophy, history, psychology, communication science and business administration. They are selected based on demonstrated education excellence, and their experience with PLE and/or multidisciplinary education.

This paper contains the reflections of the core team of lecturers on the development and implementation of the programme. We will describe the concept and underlying principles of the programme and present our interdisciplinary design-engineering model that underlies the projects. We will evaluate our first experiences and define some challenges for teaching design engineering in an interdisciplinary honours programme.

## 2 EDUCATIONAL PRINCIPLES

### 2.1 Interdisciplinary thinking

One of the aims of interdisciplinary education is to develop interdisciplinary thinking. The programme has incorporated the conditions for interdisciplinary education as presented by Spelt et al. [3]. They define interdisciplinary thinking as “the capacity to integrate knowledge of two or more disciplines to produce a cognitive advancement in ways that would have been impossible or unlikely through single disciplinary means” (p. 365). Research has shown that most programmes that claim to be interdisciplinary are in fact multidisciplinary: multiple perspectives are educated; however, students are not supported in the integration of disciplinary knowledge throughout the curriculum.

The focus on interdisciplinarity and self-regulation (§2.2) is embodied in PLE. Students work every semester on a realistic, complex open-ended project in which they must solve a problem that contains both technical and social elements. In the projects, students are confronted with phenomena that exist in both disciplines (e.g. power, feedback and interaction). The research and design skills from both disciplines are taught at the same time to learn how research and design principles can be used in the different disciplines. A unified cross-disciplinary terminology, as a design-engineering model (§2.3), is used to aid the student’s learning process. In addition, teachers from different disciplines are together responsible for the design of a semester and supervision of the project groups.

### 2.2 Self-regulated learning

The programme is designed to challenge ambitious high-ability students. Ways to do this are using complex tasks, having high expectations and low teacher regulation [4]. In addition, the programme qualifies students for monodisciplinary master programmes in both technical and social science disciplines, while they do not receive an in-depth education in every discipline. Consequently, self-regulation is crucial in order to learn how to develop and deepen themselves further in a discipline (even qualify if needed), and to deal with the challenging programme. According to Nicol and Macfarlane-Dick [5], one of the aims of higher education is to empower students as self-regulators to improve their development also in future work situations. Self-regulated learning is often seen as a personal characteristic of students, but it is also a feature of the learning environment [6]. However, in most study programmes students’ self-regulated learning skills are not developed, since they do not get the opportunity to design their own learning goals, learning activities, and assessment.

### 2.3 Interdisciplinary design-engineering model

As a basis for the design projects we use an interdisciplinary design-engineering model, as shown in Figure 1. This model is based on existing models in engineering and social sciences. In this model, design is defined as the collection of activities aimed at developing working solution(s) for various societal-technological problems and opportunities. The activities are planned, systematic and transparent, and follow an iterative and/or chronological order. The different activities feed from knowledge products of fundamental and applied research from various disciplines, which implies that research and design go hand in hand. The collection of design activities consist of six main categories

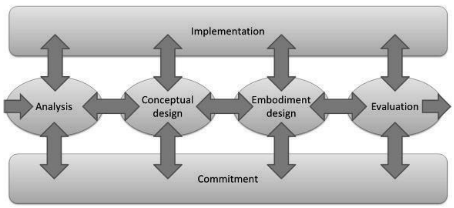


Figure 1. *ATLAS socio-technical inter-disciplinary design-engineering model*

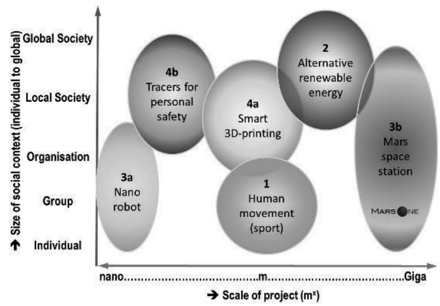


*Figure 2. Themes per semester showing the programme's breadth*

that are discernible in the various fields: *Analysis* of problems and recognition of opportunities, as well as identifying causes, needs and requirements relevant to the problem or opportunity at hand; *Conceptual design,* referring to all activities aimed at constructing a blueprint of an actual solution; *Embodiment,* constructing a concrete solution; *Implementation,* involving activities aimed at the delivery of the embodiment in a physical and social context; *Obtaining and maintaining commitment,* of all relevant stakeholders, before, during and after the design process; and *Evaluation*, both formative and summative. As shown in Figure 1, the model is defined as a network of interrelated design activities. Depending upon the nature of the problem and the scientific discipline(s) involved, the different activities vary in their importance and relevance.

## 3 ATLAS PROGRAMME

### 3.1 Set-up of the ATLAS programme

The ATLAS programme is spread over three years (six semesters). The first four semesters are theme-based, as shown in Figure 2, covering small and large-scale projects, and ranging from the individual level to society at large. The projects are organised according to the principles of PLE [7]. Together, the themes cover a substantial part of the interacting domains of the programme. Throughout the programme, domain courses cover the relevant fundamentals of engineering, mathematics, natural science, social and behavioural sciences. The third year is individually tuned to ensure the qualification for the chosen subsequent master programme(s). Next to the domain courses, there are six learning lines running through the programme that warrant the development of general academic competences: Research, Design, Organization, Communication, Learning Capacity, and Interdisciplinarity. These are to a large extent (but not exclusively) addressed within the projects.

In order to stimulate students to become responsible for their own development and to stimulate them to excel in several domains, an integrated feedback and assessment system is designed that can be tailored to the students' personal talents and developmental paths. The educational system demands students to develop their self-regulatory skills by designing their own learning goals, learning activities and assessment. Students are also explicitly supported in developing these skills, since developing their learning capacity is one of the learning goals of the programme.

With respect to the development of self-regulation, students choose for themselves what kind of role and expertise they want to develop. The talent development of the students is supported by their own Personal Development Plan (PDP), which is formalized at the start of each semester. Consequently at the end of the semester, students are self-responsible for providing their own learning evidence. They do this by writing a critical Self-Evaluation Report (SER). The SER forms the basis for the student's semester assessment. Twice a year, students receive a summative assessment on their self-chosen evidence. Three passing levels are possible: pass with condition, pass with honours and pass with excellence. Two other possibilities are a prolonged examination (i.e. students have to provide additional evidence before the assessment can be finalized) or a hold, implicating that the student is advised to switch to another program, fitting the student's capabilities and ambitions better.

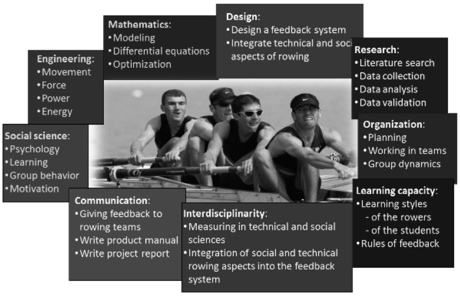


*Figure 3. Imperative fusion of domains and learning lines in Semester 1*

*Figure 4. Project result: a device to measure the rower's back angle*

### 3.2 Semester 1: project, domains and learning lines

The first semester starts with a short open-ended exercise: a three-week freshmen project about myth busting. This introduces the main characteristics of PLE, as well as the skills needed to succeed. In groups of five, students work on a self-chosen myth to bust. They learn to define the problem, to set their own goals and deadlines, to work under time pressure, to integrate both technological and societal perspectives according to the design-engineering model of Figure 1, and to work in a team.

After the freshmen project, students are placed in groups of eight and start to work on their first large thematic project, which is the backbone of Semester 1. The project is on human movement (sport) in general and last year more explicitly on rowing. Students had to design a feedback system for coaches of a rowing team, who were real-existing clients. Connected to the project, the domains in Semester 1 provide an adequate orientation of Engineering (Newtonian Mechanics), Mathematics (Calculus) and Social Science (Psychology). The contents of the learning lines are in principle self-chosen by the students, but should somehow support the project. The domains and learning lines are always intertwined and are imperative to successfully complete the project, as visualized in Figure 3. Figure 4 shows the result of one of the groups: a device to measure the rower's back angle objectively, thereby improving the specific feedback the coach can give during a training session.

### 3.3 Student guidance

In this small-scale intensive programme students are coached in three different ways: by a teacher, a tutor and a mentor. The teacher is responsible for helping the students learn the content of a domain or learning line. Tutors guide student project groups (process, some content), while mentors coach individual students (study, progress, learning and development, goals versus achievements and redirection).

## 4 FIRST EXPERIENCES

One semester into the programme, we have some interesting experiences about how to design such an interdisciplinary programme and about how talented students go about learning in a project-led and self-steering environment.

### 4.1 Experiences with the set-up of the programme

The design and implementation of the programme itself was handled as an interdisciplinary design project: many different disciplinary experts, working together as a self-steering project group to come up with one integrated solution: the ATLAS programme. During the many discussions, we had to overcome the perceived differences between the technical and social sciences, and learn about each other's disciplines and the paradigms used. As a result, we developed a design-engineering model that can be used in both technical and more social-science problems.

In addition to the diverse disciplinary expertise, the teachers also had different experiences and ideas regarding best forms of teaching. Although this led to many stimulating and insightful discussions in the preparation phase, it sometimes also led to unclear conclusions on how to proceed and to a sub-

optimal integration of all domains and learning lines into the project. Looking back, we should have agreed upon a central educational idea in an earlier stage of the programme development.
We used a general planning for the design of the programme, to make sure that everything was ready on time. As the programme was new to all the teachers and we were not certain what we could expect of the students, certain aspects of the programme (e.g. workshops, assessment procedures) were optimized while the programme was running. Although the final decisions were of good quality, the late alterations resulted in workload peaks for the teachers, specifically around the assessment of the projects and of the complete semester. A good planning in the design phase of the programme, as well as making concrete decisions well in advance could help to diminish peaks in workload in the future.

### 4.2 Experiences with project-led education and interdisciplinarity

The three-week freshmen project was designed as an introduction to PLE, which functioned well. Students indeed learned to work as a team on a relative large assignment and got a good impression of what PLE is about. Students had to use their high-school knowledge and creativity to solve the problem. We noticed a general failure to make a thorough analysis of the problem, thereby remaining only at a superficial level and going for the quick solution. During a reflection session, the students indicated that they could have gone much deeper. Apparently, deep analysis and challenging yourself does not happen naturally, not even for ambitious talented students.
From the start, the human movement project was designed in an interdisciplinary way, including both technical aspects as well as social aspects. Knowledge from different fields was necessary to come up with and design a solution to the problem at hand. The integration of these fields, however, was not a natural step for the students. Most of the project groups divided the problem into two different aspects: a technical part and a social-science part, each with their own sub-group of students working on that part. The two parts were combined at the end of the project for the final product. Hence, the real integration of fields failed to materialize in most groups. The tutors tried to stimulate the students to work more on this integration, but apparently this needs much more attention. Next year the project description will be improved in such a way that the solution should be a natural integration of knowledge fields. Furthermore the tutors will force the students to focus much more on the integration of different domains in the final project outcomes.

### 4.3 Experiences with self-regulated learning

Writing a PDP at the start of the first semester posed a challenge for the students. Many were still unsure about what they wanted to learn and what kind of master programme they are aiming for, and thus described their personal learning objectives in a very general and broad manner. As a result, the PDP often could not be used effectively to direct their learning during the semester. A learning-style test (ILS [8]) taken halfway the semester also indicated that many students were not really aware of their own learning strategy, nor working consciously to improve this. We feel that this lack of self-awareness regarding their learning is likely caused by the fact that high-school programmes are not challenging enough for them to confront them with the (in) effectiveness of their learning strategies. Next year we will pay more attention to the development of the individual learning skills even earlier.

### 4.4 Experiences with student planning

Students indicated that they missed a clear structure in the programme. Even though the limited structure is core to the ATLAS programme and we therefore often informed the students about this, they were struggling with the broad description of the project, the limited number of guidelines, the self-directedness of the programme and the absence of intermediate deadlines. In the beginning of the project students did not spend much time on their project work but focused more on the assignments for the different domains and learning lines. As a result, they had to work much harder at the end of the semester, to make sure the project was finished before the deadline. That many of these talented students do not have good planning skills might seem strange at first, but is probably due to the fact that their cognitive talents always allowed them to immediately oversee the limited-size projects they experienced in high school. Moreover, most high-school programmes are very structured, thus diminishing the need for good planning skills. Next year we will introduce a few intermediate deadlines in the project to help getting students on track.
The lack of a structured programme, with only a very limited number of lectures and workshops, also gave the students the impression that they did not learn enough during the semester. However, at the

end of the semester when the students had to reflect critically on their learning, almost all indicated that they learned (much) more than they had expected.

### 4.5 Experiences with the guidance and assessment of the students

During the first semester we monitored how the students were doing, using assignments, take-home tests and class observations. For most students the teachers felt they had a good impression about their progress. This impression proved to be right, as the final verdict at the end of the semester was for almost all students perfectly in line with the impressions halfway the semester.
The tutor’s role is to help each student group with their project, focusing mostly on the process of the project work and the cooperation within the project team. We started with two tutors per project group, one with a technical and one with a social science background. We experienced that some steering by the tutors was necessary and that the combination of a technical and a social science tutor helped the students, as they each guided the group from their own perspective.
The mentor is the individual coach of the student, focusing on the general development of the student and the planning of his/her learning and the actual learning. Both tutors as well as mentors had regular meetings with the students. Similarly, the coaches met regularly to discuss student impressions so far. With this combination of different coaches, we had a good overview of the progress of all project groups and of the individual students.

## 5 CONCLUSIONS

This paper presented the interdisciplinary BSc honours programme of ATLAS at the University of Twente with its unique focus on technology and its implementation of PLE. Interdisciplinary thinking is demanded by the project descriptions by requiring the integration of both technical and social perspectives. For this an interdisciplinary design-engineering model was drafted by the core team of lecturers and taught to the students. To challenge ambitious high-ability students, PLE principles are enriched with self-regulated learning. Students draw their own learning goals in their PDP, work on them in the project and finally reflect critically on them in their SER. This is similar to what professionals must do in their working environment.
First experiences are shared based on the first semester rollout of this programme. When designing such an interdisciplinary programme, the team should be interdisciplinary itself as well. One needs to take time to learn from and overcome the differences in ideas and experiences between different disciplines. A good detailed planning can help with this, as well as taking important decisions well in advance. Even ambitious high-ability students are naturally inclined to go for the easy solutions without digging deeper. Forcing yourself to dig deeper and really challenge yourself must be demanded by the complexity of the project and the necessity to natural integrate the various knowledge fields. Similar observations were made with respect to the student’s planning abilities. Most high-ability students have never felt this need and feel therefore unsecure when challenged with high workloads and competing task descriptions. This insecurity gives them the impression that they are not learning enough, when actually (in most cases) the contrary is true.

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# SOCIAL COHESION DESIGN, A COURSE FOR DESIGNING COMMUNITY INTEGRATED PRODUCT SYSTEMS

**Clemens de LANGE[1,2], Tjamme WIEGERS[2] and Joris VERGEEST[2]**
[1]Social Cohesion Design Foundation, Delft University of Technology
[2]Delft University of Technology

**ABSTRACT**
Design students are typically not educated in systematically including aspects of social cohesion in their designer practice. This paper describes the Social Cohesion Design course, an explorative project at the faculty of Industrial Design in Delft. The course aims at developing so called "Community Integrated Product Systems" for enhancement of social cohesion among community members, unlike mainstream industrial design with its focus set on an individual product-user experience. The course applies a new designer approach, the so called 3-I methodology, and constitutes part of a multi-stakeholder project in which students conduct street furniture assignments with human science-students for a real company for a real district in collaboration with the municipality, the district team, the housing corporation and the residents involved.

*Keywords: Social Cohesion Design, Community Integrated Product System, 3–i Methodology, 'Face to Face' contact, Q-board Interview, Multi Disciplinary, Scenario*

## 1 INTRODUCTION

There has been much concern in the last few decades about the social breakdown in Western societies. Social as well as medical reports indicate that our social fabric is disrupting having all sorts of negative impact of the members of the community to participate in voluntary work, politics, associations and on their physical health conditions [1,2]. Technology is seen as having an active role in this. A TV set binds people to their homes less visiting friends. A micro wave facilitates family members to eat at different time intervals less socializing at the dinner table. The increase of social media has a vast impact on decline of 'face to face' contacts.

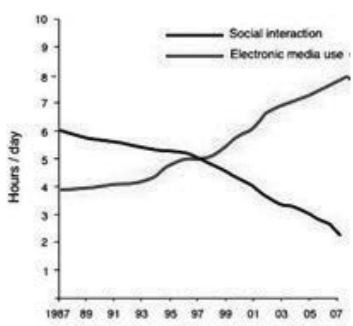


*Figure 1. Social Interaction vs Electronic Media Use [2]*

One of the most pronounced changes in the daily habits of citizens is a reduction in the number of minutes per day they interact with another human being face to face. In less than two decades, the number of people saying there is no one with whom they discuss important matters nearly tripled. These facts lead to the main question the paper addresses: Can designers develop technology projects that enhance social cohesion?

### 1.1 Course history

In 2009 De Lange, lecturer at the faculty of Industrial Design Engineering and director of the Social Cohesion Design Foundation (SCDF) in Delft developed the Social Cohesion Design course to educate design students in including aspects of social cohesion in their design practice. At the time typing in the words: 'Social Cohesion' and 'Design' in www.google.com produced zero hits. The course was named "Social Cohesion Design" stressing the starting point of the course that social cohesion is designable. The course introduces new design concepts and a new research tool inspired by Stephenson's Q methodology [3]. During the period of 2012-2014 the focal point of the course became the development of street furniture projects in Delft districts to stimulate 'face to face' contact between residents. The course is set up as a multi stakeholder project, organized by De Lange's SCDF, including students from different schools and universities, the municipality of Delft, its residents, the housing cooperation, and the street furniture manufacturers involved.

### 1.2 Explorative course development project

According to Heidegger: "the essence of technology is by no means anything technological" [4]. The essence of technology is how technology presents itself in time, how it reveals its impact on for instance social interaction among members of a community exposed to the technology. This insight is considered the "raison d'être" of this course development project since its intention is to start from the impact as envisioned by the designer and works back to the creation of a material design. The essence of the design as such is not the design itself but the Social Cohesion it provides. Since there was no model for a Social Cohesion Design course to draw from, new concepts had to be developed. The course introduces two new concepts: the CIPS, the concept of a: "Community Integrated Product System", and 3-i Methodology, the logical framework of the course. Furthermore additional sub-concepts were developed to support the logical framework such as: 'Setting X', '3D Scenario Board', 'Q Board research', 'Sub-scenario Matrix Tool'.

## 2 COURSE METHODS

### 2.1 Community Integrated Product System (CIPS)

A CIPS can best be seen as a product-embedded-community-structure providing community members the facility to pro-actively meet 'face to face' with other community members while using, maintaining, designing, promoting etc. the product at hand.

This pro-active aspect of CIPS design is seen as one of its main assets, since it helps to provide 'capabilities' to community members for social interaction and wellbeing as expressed by Sen [5]. As such CIPS design clearly distinguishes itself from "mainstream" product design with their focus set on a user-product experience. CIPS design in the end is about people having 'face to face' contact with other people beyond the product-user experience. Furthermore, CIPS design is considered in line with the trend in western economies to shift from 'goods-dominant' economies to 'service-dominant' economies as described by Varga and Lusch [6].

### 2.2 3-I Methodology

The course methodology is called: 3-i. 3-i represents the three stages in the course that comprise the CIPS design process: i-1 the Identification stage, i-2 the Integration stage and i-3 the Implantation stage.

#### *2.2.1 I-1*

In the i-1 stage students visit and explore the community of their assignment and try and identify elements (a school, households, a shop, an elderly home, a community centre, etc.) in the community that may play a role in a future CIPS scenario. Based on their choice of elements they define their "Setting X" and make a maquette of this community. This maquette is called the "3D Scenario Board" as it refers to envisioning, and communicating scenarios with stakeholders and experts involved such as the district team, the district residents, the housing corporation and guest-students from human science.

*Figure 2. Students discuss scenarios at the 3D Scenario Board*

Setting X may be the entire neighbourhood, a part of the neighbourhood, a housing block or row of neighbours in a street, depending on the students' perception of their target community. The scenarios in the future CIPS may best be clarified by a schematic representation. E1, E2 and E3 represent the selected elements in Setting X. T represents the future technology. The ellipses represent the sub scenarios including elements and technology.

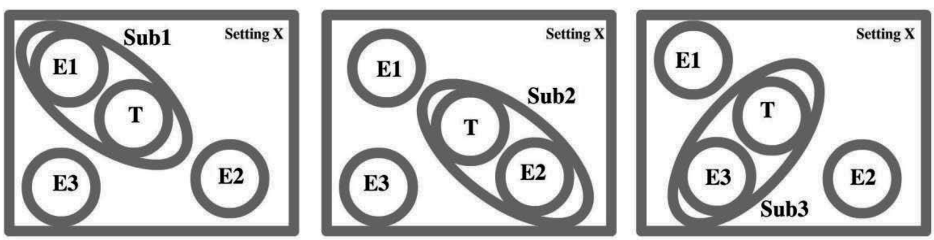


*Figure 3. Schematic representation of 3 sub scenarios in Setting X*

#### *2.2.2 I-2*
In the i-2 stage the students discuss these individual scenarios using their 3D Scenario Board and try and blend them into a main scenario. At this stage they are assisted by students from Human Science who join the design students in so called 'Inspirational Multi-Disciplinary Sessions'. The idea being that Human Science students have a different view compared to technical students when looking at the same issue. Collaboratively they develop and formulate the 'main scenario' that the IDE students use as a starting point for their material design process: the process of ideation, sketching and modelling as in classical "mainstream" industrial design.

#### *2.2.3 I-3*
In the i-3 stage the team works out a "Branding, Promotion and Pilot Plan (BBP)" in collaboration with the experts in the community such as the housing corporation, the district team and the district residents for the realization of their CIPS. The BBP plan contains a step by step manual for the realization of the project in the neighbourhood by the company, the district coordination team and the district residents.

### 2.3 Q Board Interviews
To receive feedback on their scenarios, concepts and plans from the stakeholders, students conduct 'Q board Interviews' as inspired by Q Factor Analysis. Based on these Q results they work out their scenarios into concepts and elaborate on technical construction details, outline a cost-estimation for

the production and testing of a prototype and work out a ‘step by step’ manual for the district team and the local stakeholders involved.

*Figure 4. Conducting Q Board interviews*

### 2.4 Lectures, student-presentations and course assessment

During the 10 weeks course, the students attend lectures on basic course concepts such as Social Cohesion, CIPS, 3-I Methodology, Q board Interviews, and other course concepts. The final presentation is a public presentation held in front of a jury consisting of residents of the neighbourhood for which they conducted the assignment. Best team wins the so called “Wise Owl Award”. This design is to be realized. The final CIPS design of the students is assessed by the coaches on their perceived impact on ‘face to face’ enhancement in the district and on its design and feasibility qualities.

## 3 RESULTS

In 2010 the course took off with a CIPS assignment for a slum settlement in the ‘Base of the Pyramid’. CIPS concepts were developed for a Community Integrated Pedal Power Game System where students envisioned community members to collaboratively pedal power in a playful way to charge their batteries to run their LED lamp, and for a Community Integrated Garbage Collecting System where materials were sorted out and distributed among workshops to fabricate new products such as bags.

*Figure 5. Pedal Power LED concept and Garbage collecting concept, 2010*

In 2011 the students had to design a CIPS assignment for a coffee-distribution project for the TU Delft campus to enhance social contact between staff members. The assignment was conducted for a real company, Douwe Egberts. The CIPS concept was based on a new type of ID cards containing information about personal hobbies. Staff members log in and a common theme of interest is shown on the top display to provide a topic for a ‘face to face’ chat.

*Figure 6. Coffee machine concept for Douwe Egberts 2011*

In 2012 and 2013 the assignments concerned the CIPS developed of street furniture projects for a real neighbourhood in Delft and for a real manufacturer of street furniture.
The students developed a CIPS concept for LED lighting in flats to provide residents the "capability" to collaboratively design a light colour composition.

*Figure 7. Lighting concept for Maiken 2013*

## 4 CONCLUSIONS AND RECOMMENDATIONS

A lot of explorative research in this course development project still needs to be done. However, a first step in the 'long and winding' journey to a fully integrated multi-stakeholder project has been made. As far as including schools and universities in this course is concerned, the main challenges are the incompatibility of the educational programs, the schedules, the study load and the course validation, the number of Ects involved.
In this course inviting guest students from human science as experts to join 'inspirational sessions' may very well be a practical solution for providing Social Cohesion Design students with the opportunity to learn from and communicate with students with a different mind-set and to receive the necessary human science input in their design project. As far as including real companies in the project is concerned, no major problems were encountered and companies were easily selected on their keen interest to learn a new design approach and the new 'mind-set' that comes along with it. Including stakeholders from the municipality, the district residents, the coordination team and the housing corporation involved we do not consider the main challenge in this project as they are eager to get new ideas for social enhancement and upgrading of their district. Financing of the projects to be realized in the district however is a major challenge and as such forms the major bottleneck for testing the results of the course and the methodology in practice.

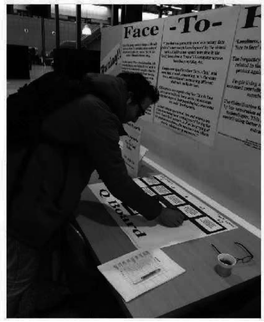


*Figure 8. Q Board interview station*

As far as the students are concerned they appreciate the collaboration with students from different universities and background and there is a general consensus among them that impact of technology projects on social cohesion must be considered. Only recently we did a Q board research project called “Warning Face to Face Decline” at our faculty where 76 students, randomly chosen from approx. 300 students entering the faculty hall and passing the Q Board station in the period 2 - 5 December 2013, were asked to rank order 9 statements referring to impact of social media, policy making, role of philosophy, and other contemporary themes. Highest ranked:
“A design is not complete if its social impact is not considered”.

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# EXPERIENCE, DESIGN, A STUDENT POP-UP SHOP

**Andrew FORKES and Barney TOWNSEND**
London South Bank University

**ABSTRACT**
This paper presents the experiences of staff and second year BSc Design students at the Authors' Institution in developing a 'pop-up shop' event over three consecutive academic years. Students were given a short period of time (3-5 weeks) in which to design and manufacture a small gift item, which could be sold at the event. They worked in small groups to explore the systems, service, marketing, graphic, and experience design of the show, and then in teams to produce, market, and run the event. Individually, each student designed their product to the requirement to sell it for a demonstrable profit margin at the event, and the need to be able to batch manufacture it to order during the subsequent week. For many this was their first experience of working to an externally imposed deadline with the potential for real income generation from their design skills. Students developed a broad spectrum of design and entrepreneurial skills, deepening their understanding of the traditional role of a product designer while reflecting on the value of enterprise skills for their future careers in industry. This paper will contextualize the project within the Design syllabus at the authors' institution and the wider industrial environment, and concludes with some reflections on the value of the project for student learning, and suggestions for teachers of design in considering similar pedagogical approaches.

*Keywords: Product Design, Innovation in Teaching, Enterprise Education, Experience Design*

## 1 INTRODUCTION

### 1.1 Context

'Entrepreneurship education can both accentuate individual achievement, and provide opportunities for team work and the development of other 'soft' skills that are so valuable to business and society today' [1] The research 'Entrepreneurship in higher education, especially within non-business studies' carried out by the European Union in 2007 suggests that the provision for entrepreneurial activities in higher education is stronger within business oriented courses but is lacking in other disciplines, such as art, design and engineering, although viable innovations and business ideas often stem from those disciplines [2]. The objective of the project described in this paper was to integrate entrepreneurship into a design curriculum in a manner that enriches theoretical study with practical experience, by giving students the opportunity to test their design skills in a real marketplace and the academic to adopt the rare fusion of a collaborator/commander of the process [3].
The concept of pop–up retail emerged circa 2004 [4] as an immediate and cost effective way of selling goods and services within short-term shop environments. This formed the inspiration for a student project that would use the selling activity as the driver for a material based design project, using appropriate locations and available resources within the campus. Inclusion of enterprise within the curriculum is central to the policy of the authors' institution for developing entrepreneurial students.

### 1.2 Design of the Project

The 'pop-up shop project' was developed for a second year cohort of students on BSc Product Design and BSc Engineering Product Design courses. During their first two years, the students from both courses study several common modules that cover a broad and fairly typical spectrum of design skills including design methods, drawing, prototyping, CAD, graphics, and sustainability, with separate modules in Design Engineering, and Human Centered Design to differentiate between the two courses. Both courses have a long heritage of positioning making at the center of the design process, supported by a strong engineering and prototyping resource base that includes additive, formative, and subtractive technologies, and craft based methods. Enterprise skills are introduced implicitly during the first year, and developed to a greater extent during the second year taught courses, but in the past the students had little opportunity to put these into practice; they were not formally assessed on these skills until the final year, which incorporates a specific module in 'Innovation and Enterprise', before they are expected to apply those skills to their Major Projects. The novelty of this project therefore lies in the exposure of students to real enterprise activity at this relatively early stage of their academic studies.

The objective of the project was to provide a practical entrepreneurial experience that would develop and enhance multi dimensional components of their thinking by embedding enterprise skills such as team working, collaboration, branding, promotion, sales, and marketing, and intellectual property protection, in addition to more traditional design elements of creativity, concept generation and selection, iteration, experience design, product development through prototyping and an insight into 'just in time' [5] and batch production methods.

The students' core discipline was the driver for the entrepreneurial activity; in this case, designed products are the key skill, so a range of good quality and innovative products were required to form the basis for the entrepreneurial activity. The teaching team believes that "Good design is good business"[6]; enterprise based upon a poorly conceived or developed product proposition is a wasted opportunity. Thus the theoretical drivers for the design of this student experience might best be described as "design led entrepreneurship".

## 1.3 The Project Brief

The project was developed over three consecutive years, and the brief was necessarily adapted year on year as the tutors learned from experience and endeavored to streamline and improve the learning experience. However, the core components remained the same, split between collaborative work on the design and production of the pop-up event itself, and the individual design work on the products that would be sold at it. These activities are described below as distinct phases for clarity, but in practice they occurred in a far more concurrent manner.

### *1.3.1 Phase 1: Event Design (group work)*

The design and marketing of the event itself was a crucial component of the learning experience, and this was led with the branding. Working in groups of 5, students brainstormed the multi-faceted components of what it means to be a design student at this particular institution, and what they wanted to communicate to potential customers via their marketing strategies for the event. These ideas were developed for various media, and supported by further exploration into all aspects of the event, from product literature and plinth designs, to cash flow and order tracking systems, and uniform clothing to be worn on the night. One constraint on their designs at this stage was the venue, which was effectively predetermined by the spaces available for use within the University. The students were provided with building plans, enabling them to explore layouts in both 2D and 3D CAD, and through physical models.

By way of simulating of the intensive nature of real-world design projects, and of making professional pitches, the groups were given just one week to develop their proposals before pitching their concepts to the entire cohort. During the first two iterations, this consisted of a PowerPoint presentation supported by models, but for the third year, students were encouraged to use video as a medium, which offered an additional learning experience of communication through alternative media.

Following the presentations, the entire year group conducted a multi-voting concept selection exercise in order to democratically identify the most popular ideas to take forward. Given the holistic and multifaceted nature of the proposals, it was inevitable that each carried both merits and disadvantages, such that it would have been difficult to simply adopt one proposal in its entirety. Thus the voting was broken down into key conceptual themes – the brand, the marketing strategies, the show layout etc.

### *1.3.2 Phase 2: Product Design (individual work)*

Students were given 3-5 weeks in which to design, develop, and prototype manufacture a small gift item to be sold at the event. The emphasis was not only on the creative design of a novel or engaging product, but on careful consideration of the manufacturing process such that their product could be efficiently costed and batch produced to order during the week following the event.

For the first year of the project, material usage was restricted to a small palette of A4 sized samples in order to promote material driven design coupled with a relatively simple costing system template that

could be used as the basis for determining retail price. The students were limited to planar card, acrylic, plywood, cork, or felt, to be laser or hand cut, and assembled into three-dimensional forms.
Following the successful implementation of this, the material palette and the tools available were expanded the following year, in the hope of encouraging a broader range of creative outputs. Students were permitted to use any of the manufacturing technologies available within the University Engineering and Design workshops.
Common modelling materials designated as standard stock are normally provided free of charge to the students. Whilst some of these are primarily prototyping materials that are less suitable for saleable products (MDF, modelling foam), others like plywood and acrylic were in high demand. Students had free access to stock materials for prototype iterations in the development stages of the design work, and for their "shop ready prototype" to display at the event; if further materials outside of this range were needed, those who made sales would be reimbursed pro-rata according to the sales that they made. This encouraged professional judgment in their material selection, but also consideration of the inherent risks associated with entrepreneurship.
Students were introduced to a broad gamut of the production processes available through the taught curriculum that ran concurrently with the project. In addition to 'standard' processes, they were encouraged to adapt or subvert technologies to achieve their desired result. This was led by examples from the academics' own research and practice.

#### *1.3.3 Phase 3: Event Production (team work)*
After the core branding and production concepts had been selected, the groups were broken down and reassigned as teams to implement the decisions that had been made. This remixing was designed to ensure that students learned to work with new members of the cohort who they might not previously have encountered. The teams fell into three overarching categories, with roles that overlapped but generally took precedence at different stages of the event planning. The Graphics Team started work immediately to refine the chosen brand, tying the disparate concepts that emerged from the selection process together into a coherent whole, and to translating it to the various promotional media that had been chosen. The Marketing Team would take over during the two or three weeks before the event, implementing the marketing strategies and ensuring that the promotional materials were distributed according to the proposed plans. Finally, the Event Team would take over on the day of the event itself, organising and hosting the customer experience, and tracking sales. Students elected to join these teams based on affinity to a particular skill set. They then elected team leaders, and managed their teams autonomously with very little guiding input from the tutors.

#### *1.3.4 Phase 4: Batch Manufacture*
As describe above, the event was scheduled for one week before the end of the term, so that students who sold items could have time to manufacture the products that they had sold to order during the subsequent week. This required them to consider very carefully their production times when making sales at the show, so that they could ensure that this was possible within the timeframe, and if necessary, limit the number of orders they took. They were required to complete this activity in their own time, outside of scheduled classes, although there was considerable academic oversight at this stage to ensure that all orders were fulfilled. In most cases, the customers were from within the institution, and the students took pleasure in personally delivering their products to their customers.

### 1.4 Assessment
The marking schemes were developed to allow both formative feedback at interim critique stages, and summative assessment at key milestones. The resultant grades were compiled from components of group work on the branding proposals, individual design work on their personal product, and individual contributions to the team production of the event. This staged assessment allowed the teaching team to gauge if any 'crisis meetings' were required with individuals or groups to ensure the deliverable was achieved.
The assessment criteria were designed to allow for recognition of exemplary work, for students that excelled in a particular role to gain the appropriate marks for the effort and evidence of good team work or individual project work. Crucially, it was recognized that this 'live' sales environment is still somewhat artificial, and thus there was no direct link between individual sales of products and grades. Successful sales represented a personal badge of honor for the student, but their grades for the

individual design work were based upon innovative thinking, the design processes they employed, appropriate use of prototyping, and a full and comprehensive costing of the product for timely small batch manufacture.

## 2 IMPLEMENTATION

### 2.1 Year 1: ‘Pop-Up Shop’

Despite several alternative name proposals, the students elected to stick with the original title, choosing a brand that played on this in a Pop Art style. The event was held in one of the large teaching studios, on a Friday night one week before the end of the Christmas term in 2011. Students added gel panels to the fluorescent lighting boxes to give the room an unusual ambience and provide a visible way marker for the exterior of the University. Product literature was produced in the form of a plastic ID card for each student, printed by the students using a card printer borrowed from the LSBU security systems. The cards were suspended from the ceiling of the room on fishing wire, floating above the work on tables below. Students created T-shirt uniforms using iron-on cut vinyl. Products that sold included Christmas related puzzle games to assemble a Santa statue, decorative jewellery stands, mobile phone holders and cases, and 2½ dimensional Christmas cards incorporating laser cut ‘gifts’.


*Figure 1. The graphic and selected products from the ‘Pop-Up Shop’*

### 2.2 Year 2: ‘The Design Practice’

In 2012, the students elected the name ‘The Design Practice’. The event was held in the newly opened Student Centre building, a prominent location that offered the advantage of accommodating the larger student cohort from that year group, but also imposed stricter limitations on what could be done with the space. In addition to the Friday night event, the opportunity arose to open the shop again the following Monday morning in order to reach more passing traffic, which had a positive effect on sales. The implications of opening up the materials and process palette from the previous year were manifest in the range of products that the students produced. Products as wide ranging as bicycle mudguards designed from recycled plastic bottles, silicone moulded headphone tidies, candles made from wax cast into 3D printed moulds, and laser cut acrylic fruit bowls were sold.


*Figure 2. The graphic and selected products from ‘The Design Practice’*

### 2.3 Year 3: ‘Designers Assemble’

2013 saw a further rebranding to ‘Designers Assemble’, with a powerful graphical theme based upon the concept of the superhero designer. This year group also proposed innovative marketing methods, with pop-up 3d invitations for University VIPs and guerilla tactics such as ‘superhero mask’ stickers on the mirrors in lifts. The venue for the private view remained the same as the previous year, but this time the Monday shop opening was held in a vacant street facing commercial unit in the University’s newly opened 'Clarence Centre for Enterprise and Innovation'. This enabled the students to pitch their products to the general public, and several sales were made to passing pedestrians. A student proposal for profits to be donated to charity was almost unanimously agreed upon by voting. Products that sold included a pink laser cut wine bottle holder in the shape of a pig, magnetic flower vases from test tubes and machined mahogany, and desk lighting.


*Figure 3. The graphic and selected products from 'Designers Assemble', and the group outside the shop*

## 3 DISCUSSION

### 3.1 Design and Implementation

During the first two iterations, all of the project work took place during the 5 weeks immediately preceding the event. This inevitably led to an intense and stressful final few days as everything was being manufactured, which required the tutors to keep the workshops open until late into the evenings. Although this 'ramp up' was probably to be expected, it was disconcerting to see some students queuing for the laser cutters with minutes left before the show opened. In 2013, the teaching and design work phase were advanced to the first 6 weeks of Semester 1, leaving a 6 week break before the actual event. This allowed the students more time to act on feedback from the assessment critique to refine and produce their products, but it also highlighted an issue in the students' attitude towards the assessment. Despite clear instruction that no additional marks would be awarded for the product design component after the submission date, many of the products were nowhere near being ready for sale at this point, and the grades were low accordingly. In previous years, the impending show had imposed an immovable and clear deadline – students knew that if the work was not ready, they would not be able to exhibit, an unavoidable penalty that they alone had the power to avert. When the design work was formally assessed 6 weeks before the show, the resulting effort at this point was reduced. This may be suggestive of a motivation that is less concerned by academic grades than by the satisfaction of presenting work that they are proud of to the public.

Two approaches to the multi-voting concept selection method were tested: an online survey tool for voting, and a live multi-voting session in the design studio. The latter gained far higher engagement and participation, as the students queued up to place their vote with ticks against categories on the whiteboard, amid cheers when popular concepts were voted for.

During the events, accurate tracking of sales and customers was vital to ensure that all takings were accounted for, and that all of those customers received their goods during the following week. This proved to be one of the most stressful factors for the academics, who would face the responsibility if the students failed to deliver. It was felt to be important for their learning experience that keeping track of sales was managed primarily by the students, but this was carefully overseen by the tutors. In 2013, the students used an iPad application for the sales tracking, which sent automated email receipts to both the customer and the academics. This successfully reduced the amount of manual paperwork that the previous events had incurred.

### 3.2 Profit and Loss

Although the primary driver for this project was the student experience of enterprise activity, rather than tangible commercial profit, a clear but small profit was made each year, when accounted against only those students who actually made sales. Inevitably not all of the students achieved this, but the design of the system limited these losses to the cost of the single prototype on display – no stock was held beyond the display model, so no sales meant no further loss. These could therefore be written off against the prototyping budget available for the module, rather than against the gross sales. Total profits margins improved from around £70 in 2011 to a total of £350 in 2013 – a measure of the improved design of the project year on year.

## 4 CONCLUSION

The group elements of the project allowed students to elect themselves into distinct roles based on their personal aspirations and key skills, encouraging them to reflect on roles they may have carried out in their Saturday jobs in bars or shops, and transferring this knowledge to contribute positively to their design experience. Observations made at the events highlighted the novelty and richness of the learning experience for the students. Although they worked as a team towards the success of the holistic event, they were also, in effect, in individual competition with each other to make sales – a further simulation of the realities of real-world enterprise. The atmosphere amongst the social group at the events, although entirely good natured, was highly charged and excitable, and it was a rewarding experience for the academics to see the delight on students faces after they had just sold their first product; in most cases, this was the first experience they had ever had of using their design skills to generate real income.

At every event a feedback board was provided to receive comments from the public, which were overwhelmingly positive. The project has been well received internally within the University and was highly commended at the 'Vice Chancellors Enterprising Staff awards in 2013. It was also specifically commended by the inspectors from the Institution of Engineering Designers during the course re-accreditation in February 2014. The project has and continues to achieve its objectives of promoting unity within the cohort, strong teamwork based on collective goals and academic alignment for the next stage of study. The experience of developing and testing their work for real potential customers offered the students new insights into the role and importance of enterprise skills in their future careers, and there was evidence of this in the reflective reports that formed the final part of the submission after the event. The project has now been embedded firmly within the design curriculum for second year undergraduate level Product Design and Engineering Product Design students. The teaching team will continue to develop the project to reflect both feedback from the previous students, personal reflections on improving the process and the authors' research into rapid prototyping technologies and the maker movement.

Future development on this project might be to explore the implications of cross-disciplinary team working, by inviting students from the business school to participate in it. Also, profits might clearly be increased by keeping the shop open during working daytimes for a longer period, although this carries difficult resource implications to be resolved.

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# DEVELOPMENT OF THE MATERIAL SELECTION PRACTICE – A STUDY EXPLORING ARTICULATION OF MATERIAL REQUIREMENTS

**Karen Marie HASLING[1] and Torben LENAU[2]**
[1]Design School Kolding
[2]Technical University of Denmark

**ABSTRACT**
This paper explores how the material selection matrix is used in a materials and sustainability course. The matrix encourages the students to articulate material selection requirements to become more competent in exploring new materials and selecting materials for a given design task. The study indicates that students focus on technical requirements when using the matrix and justifying their selection of materials. This is surprising since the students attend an arts and crafts oriented design school and are encouraged and guided to consider non-technical requirements, as part of the course where the matrix is introduced. A possible reason for the undesired behaviour could be that students are allowed very freely to define their own matrices, having only little guidance to which requirements to use. A more formal procedure for making the material matrices is therefore proposed. The procedure requires students to use a fixed number of technical, experiential and sustainability oriented requirements.

*Keywords: Material education, material selection methods, material requirements, applied learning*

## 1 INTRODUCTION

Materials constitute the physical appearance of a product, and choosing the right materials is fundamental for, how a product will function and how it will appear. As part of their education, product design students have to develop a material practice that incorporates material thinking in their overall design practice and this includes how materials are evaluated and selected. Guiding students to develop a structured material selection practice serves to increase the integration of material thinking in the design practice. It furthermore aims to make designers more aware and to reflect on the materials they use.

At the beginning of their education students usually have limited knowledge of materials and this knowledge is based on unstructured personal experiences. It is essential to expand their mental materials library and teach them how to explore the materials. The number of commercial materials available is rapidly increasing and the traditionally used taxonomy of material families is gradually decomposed with hybrid materials such as composites. As a consequence, it is fundamental to provide students with tools to create their own understandings of materials. Materials play an important role in, how users perceive a product and good solutions are found by examining a range of different materials and comparing the solutions based on a set of requirements.

### 1.1 Existing tools

A range of similar material selections tools that stress experience-related properties exist. Karana's Meaning of Materials tool serves to support designers in understanding key variables essential to meaning attribution to materials and to define patterns in particular material-meaning relationships [1]. Rognoli's Expressive-Sensorial Atlas is a collection of sensorial maps developed for interactive use with students stressing relative material properties by structuring materials by means of a linear scale (e.g. light/heavy, cold/hot and soft/hard), linking sensorial and technical properties by intuition [2]. Zuo's Material Aesthetics Database is a semiotic database, containing information about the sensory perception of materials that address questions such as, how people verbally describe sensorial properties and, what inter-relationships that exist between various responses to the sensory properties. [3]. Bang's repertory grid tool developed for communicating emotional properties in the textile industry builds upon the repertory grid as a method facilitating a systematized focus on relevant and available means for designing future textiles and by analytically articulating textile attributes [4]. Van Kesteren has developed three material perception tools focusing on different aspects of user-interaction in materials selection: a picture tool, a sample tool and a question tool proposed to support designers in enriching their materials terminology and understanding materials' sensorial properties [5]. Johnsson et al. proposed to use a predefined vocabulary of aesthetic and perceived attributes to grasp the more intangible requirements in material selection. The vocabulary is used in the more general design teaching at the Technical University of Denmark to train students' articulation of material properties [6].

### 1.2 Different learning approaches

These tools for exploring material awareness aim to improve the acknowledgement of non-technical properties used in material selection processes in product design. However the tools are all developed and tested on practicing designers, research staff or students from technically oriented design educations. It is acknowledged that the degree of technical orientation is not discrete being either highly technical or crafty, but a continuum space including design education within engineering, arts and craft and to a certain degree business and production. Nevertheless none of the tools directly address students from arts and craft design disciplines.

In Denmark, designers have traditionally been educated from either arts and craft funded design schools rooted in the Bauhaus School tradition [7]–[9] of practice based knowledge construction and reflective and subjective meaning creation as vital factors [10], or technical universities funded in a more behaviouristic learning tradition [11], [12] . Furthermore, whereas arts and crafts design schools have user experience and aesthetics as focal points, engineering programs weigh technical issues high.

## 2 THE MATERIAL SELECTION MATRIX

The basis for discussing the use of technical and experiential properties is the material selection matrix, an educational tool used to identify requirements and choose materials for product design concepts (described in Danish in [13]). The matrix has been used in the Materials & Sustainability course for the last five years in different formats, but has not been subject to analysis in terms of its output and how it can be used for developing material courses further. Students are introduced to the tool, first with a lecture on its components, examples of approaches and matrices made by students in previous courses and then with group guidance in, how the matrix can be applied to their concepts. Halfway into the course, students present their preliminary work, where after they improve the matrix, if essential aspects have not been included.

The structure and mindset of the material selection matrix bear resemblances to established decision-making models used in design engineering such as quality function deployment matrices [14] and Harris Profiles [15] and can be identified as a modified version of a Pugh evaluation matrix [16]. One axis lists requirements and the other axis lists relevant materials. Materials are graded depending on how well each requirement is met. The procedure in using the matrix is as follows: 1) A concept or design brief is proposed, 2) a number of relevant material requirements are identified, 3) a number of potential materials are identified, 4) materials are given marks for each requirements, 5) the summation of marks gives students an indication of the best applicable material(s). Whereas the Pugh matrix uses +/- -grading with a benchmarking datum, the material selection matrix can be graded in different ways dependent on students' preferences. This is in line with the didactic approach that students should make bad choices based on reflection rather than make good choices based on no reflection. Thus the primary purpose of the material selection matrix is to make students reflect on the requirement and selected materials they base their design on. Furthermore the matrix enables them to perform structured and systematic analyses arguing for choices made.

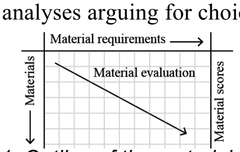


*Figure 1. Outline of the material selection matrix*

The matrix is a contextual tool in the sense that it works best if it is used as part of a concrete concept development process. This is beneficial for the design researcher, as it captures the potentials and barriers for how students approach the tool in a non-interventional learning situation and for the students since it is more likely that they integrate the tool into their design practice. The limitation is that the tool should be used only for understanding and materializing a specific concept in order to make sense.

## 2.1 Description of the study

The analysis is based on data extracted from matrices of 21 concepts developed by students within three courses in Materials & Sustainability in the fall 2012 (5) and 2013 (16) in combination with observations made during the course. The course is a three-week course on third semester for textile, fashion and industrial design students at Design School Kolding. In 2012 it was a mixed course, while the courses in 2013 were held for respectively industrial design and fashion and textiles design. The course is the last of two fundamental material courses that aim to provide students with fundamental knowledge in materials. Students are working in groups on product design projects stressing issues of sustainable use of materials. During the course students are given supplementary lectures in relevant materials and generic sustainability as well as different exercises to evoke material explorations and material awareness creation.
The matrices were made in the groups and are based on discussions and material investigations within the groups. The time spent on the matrices differs from group to group and depend on, how difficult the students find it, and the complexity of the product.

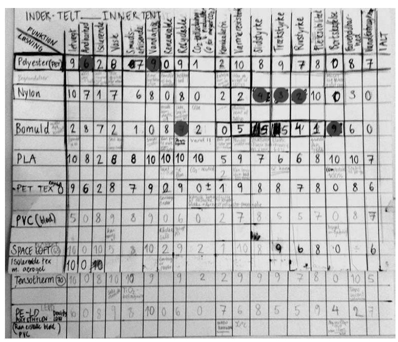

*Figure 2. Example of a material selection matrix evaluating materials for a tent canvas*

Figure 2 shows an example of a material selection matrix made by two industrial design students. The matrix evaluates materials for a tent canvas and lists requirements on the horizontal axis and materials on the vertical axis. Nine materials are graded (polyester, nylon, cotton, PLA, Eco-PET, PVC, Spaceloft (Aerogel matt), Tensotherm (PTFE/aerogel sandwich) and LDPE) using seventeen requirements (lightweight, breathability, insulating power, cleaning, dirt repellency, water repellency, recyclability, renewability, $CO_2$-emission (production), free of chemicals, heat resistancy, abrasion resistancy, tensile strength, tearing strength, flexibility, disposal and water consumption). The materials have been marked using a 0-10 scale, with additional comments placed under the marks. The empty column at right is intended for the total score for each material. The red dots do not have any function, besides correcting marks.

### *2.1.1 Modified course curriculum introducing material scales*

In the courses conducted in fall 2013, the curriculum was modified to promote the acknowledgement of non-technical material attributes. This further introduced lectures on material identities, working with online-based material libraries from Innovatheque and Material and an exercise based on relational semantic mappings.
The exercise stresses the use of non-technical requirements in the matrix and has resemblances to the Sensory Mapping tool used by Rognoli ([2], [17]). The aim of the exercise was to make the students start reflecting upon the diversity of material properties that can be evaluated and that the perception of non-technical characteristics is highly personal. When using a relational scale, students do not have to consider whether properties are measurable or not, and the order of the materials are created by the students' intuition, experience and hands-on investigations.

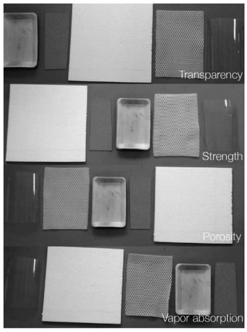


*Figure 3. Examples of material scales made by groups of industrial design (left) and fashion and textile design (right) students as introduction to the material selection matrix*

In groups of two to four, students were asked to order five or seven materials using five different material properties. The properties were free of choice, but had to include at least one of either technical (objective) or experiential (subjective) properties. When analyzing these properties it was revealed that predominantly technical properties were used and that the group making of the relational mapping stimulated dialogue and discussion. This forced the students to articulate and express subjective believes, and longer discussions were often required in order to agree upon, how materials should be placed.

## 3 FINDINGS FROM USING THE MATERIAL SELECTION MATRIX

Two aspects have been of interest in the analysis of identified requirements: the nature of the requirements and how they are structured. The former is important in order to understand the diversity of requirements being considered in material selection and the latter in order to understand, how students approach this process.
A total of 291 requirements have been identified in the three courses. In table 1 an overview of the requirements identified is given. Of the 291 requirements approximately 120 were distinct; a number that is not definite as some requirements overlap and vary in detailing.

*Table 1. Overview of the requirements identified in the course in 2012 and 2013*

| | Groups / components | Requirements |
|---|---|---|
| Mixed course 2012 | 5 / 6 | 64 (average 10.7) |
| Fashion & textiles course 2013 | 9 / 11 | 131 (average 11.9) |
| Industrial design course 2013 | 4 / 8 | 96 (average 12.0) |

***The structure of material selection matrices***

Even though the curriculum changed from 2012 to 2013, no remarkable differences occur in terms of structuring the matrix. Four main trends of characterization of structure appear:

- The majority of matrices show no structure and requirements are seemingly randomly selected and distributed
- Requirements are structured in terms of the product life cycle, grouping requirements in terms of e.g. raw materials, production, use and disposal
- Requirements are divided into functional/technical and sustainability assessments properties
- Few groups (two) have assessed materials using sub-groups containing few non-technical properties

***The nature of material requirements***

Even after the course curriculum was modified, the requirements tend to have technical orientation, and less than nine of the 120 distinct requirements can be characterized as non-technical. These are 'softness', 'comfortable', 'nice tactility', 'Aztec-like', Inuit-like', 'smooth', 'patina', 'signalling effect' and 'trend appeal', A larger fraction (30-35 requirements dependent on how sustainability is approached) accounts for sustainability issues, typically combined with a product life cycle structured matrix. Examples of these are 'separability', 'renewability' and '$CO_2$ emission in production/disposal'.

Requirements are predominantly related to either production (raw materials, energy consumption, manufacturing processes etc.) or practice of use in terms of durability and maintenance (e.g. mechanical, chemical and thermal properties), which also has been indicated in a previous study based on the material selection matrix [18].

## 4 DISCUSSION

In constructivist and applied learning it is stressed that students should be left room for subjective interpretations of methods in order to develop individual practices [10], [11]. This has also been the case for using the material selection matrix in the materials teaching. It is difficult to conclude whether the matrix is a better material reflection and selection tool than others, as it has not been compared to others in the given context. The general expression among students is that the topic (materials selection and sustainability) is overwhelming and being required to reflect on and discuss materials selection in a structured manner is difficult.

With that said, students are challenged in multiple ways. They are being introduced to a structured selection method that forces them to reflect on their decisions, they are being introduced to a complex world of materials that can be fascinating, however yet frustrating and overwhelming to navigate in, and they have to do this within the boundaries of design for sustainability, which in itself and for even the trained designer can be a challenge. With a time frame of three weeks students express the necessity of spending time afterwards to reflect on using this method that challenges their awareness concerning product requirements and materials, as well as their use of methods in their practice.

The limited material knowledge the students have and the few lecture given in the course are by some means advantageous, as it gives open-mindedness, and encourages students to explore different kinds of materials without being (too) restricted by presumptions. Nevertheless it is also a challenge, as students tend to hold on to what is already known, and even though it is maybe not the vocabulary they would use to describe their practice preferences, technical attributes seem to be the predominant way to communicate materials. Stressing non-technical requirements and using a tool like the reflective semantic scale may have opened students' eyes to, how materials can be evaluated, but even further emphasis on non-technical properties is necessary.

Based on the analysis of the material selection matrix, it is proposed to introduce a modified matrix to provide structure and guide students in their material selection, though still challenging their reflection on material choices. This aims to provide a tool that further forces students to consider technical, experiential and sustainability assessment requirements on equal terms. The approach breaks with the previous liberal and open approach, but it serves to make experiential material characteristics more than just gimmicks or second rang requirements. Because sustainability assessment requirements can be both technical (e.g. raw materials, energy consumption, recyclability etc.) and experiential (e.g. prolongation of use based on emotional attachment), they are intertwined in the two otherwise contrasting categories of requirements.

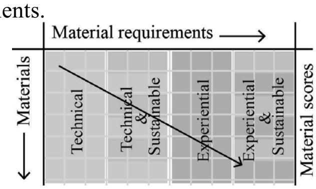


*Figure 4. Schematic outline of the modified material selection matrix*

To ensure higher quality and relevance in requirements used, it is proposed to apply a prescribed number of technical and experiential requirements. In the 2013-Materials and Sustainability course an average of twelve requirements were used in the matrices. The requirements used were relevant in general but could be formulated more precisely. It is therefore proposed to introduce a matrix with twelve requirements that have to comprise an equivalent number of technical and experiential requirements, thus six for each. When further addressing sustainability issues on equal terms, sustainability assessment requirements account for three of the six in each.

## 5 CONCLUSION

The paper discusses the experiences with an educational tool, called the Material Selection Matrix, used to create material awareness. In three studies a total of 18 groups of students have used the matrix to choose materials for 25 components. They defined 291, where 120 were distinct, 9 related to emotional properties and 30-35 related to sustainability issues in material selection.

The majority of the matrices show no structure and requirements are seemingly randomly selected and distributed. In some cases requirements are structured in accordance with the product life cycle, grouping requirements in terms of e.g. raw materials, production, use and disposal or into functional/technical and sustainability assessments properties. Few groups assessed materials using sub-groups containing few non-technical properties. Introducing exercises with material scales to promote non-technical material attributes did not have any significant importance.

The previously applied didactic approach has aimed to give students freedom to construct and structure the matrix, as they found best, as it was believed to establish the best premises for creating reflections and awareness in the material selection process. However the paper indicates that students find it difficult to structure their material choices and to consider experiential and sustainability assessment requirements when selecting materials using the introduced matrix. Students consider technical properties, even when being encouraged and guided to do differently in the process. It is therefore proposed to introduce a modified material selection matrix with a more defined structure and stricter guidelines to, how it should be used.

The findings presented in this paper have built a foundation for improving the matrix. The modified matrix has not been tested and therefore it is not possible to conclude how it works yet. As an educator this study can function as inspiration for questioning tools and methods used. This project has offered the opportunity to reflect on the didactic approach to materials teaching and aims to create better knowledge for educators in the materials and design field.

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# FLAT DESIGN VS. SKEUOMORPHISM – EFFECTS ON LEARNABILITY AND IMAGE ATTRIBUTIONS IN DIGITAL PRODUCT INTERFACES

**David OSWALD and Steffen KOLB**
HTW Berlin University of Applied Science

**ABSTRACT**
In 2013 Apple introduced a new interface design for their mobile devices. Whereas the previous design language made heavy use of real world metaphors and cited material like wood, paper, and leather, the new interface now has a reduced and immaterial look. Avoiding metaphoric imitations its colourful graphic language is mostly non-representational. The pros and cons of both interface design approaches have been discussed in the interface design community ever since. Apart from aesthetic judgements, especially the question of usability and learnability has been debated heatedly. In this paper the theoretical concepts that are relevant for usability and learnability discussion, and a survey on how the interfaces' reception changed over time, will be presented.

*Keywords: Interface design, multi-touch, mobile, flat design, skeuomorphism*

## 1 INTRODUCTION

In the last decade, the amount of products that integrate digital interfaces has increased significantly. In this domain of hybrid products, product design education should address also developments and trends in interface design. A recent trend gained momentum when Apple released its new operating system for mobile devices (iOS) in September 2013. It employs a colourful, yet abstract design language, [1] abandoning the approach Apple had been following for the past six years. The old design approach was based on imitating real life artefacts, their physicality, and their materiality. Critics of these imitative interfaces introduced the term 'skeuomorph' [2] – suggesting that this approach is decorative and lacking reason in functionality and usability. In contrast, the new approach abstains strictly from using faux materiality and three-dimensional effects like drop shadow, hence its byname 'flat design'.

Interfaces today are partly based on dominant and cognisant metaphors like the 'book' or the 'waste paper basket', which provide models for whole operating processes and interaction sequences. But also on a small-scale level, interfaces make metaphoric use of physical analogies that indicate which parts a user can press, click, or slide, etc. These phenomena have been described as 'indicating functions in product semantics [3] and as 'affordances' in cognitive psychology [4] One of the criticisms towards flat design is, that it lacks these affordances and therefore is less self-explicatory and less usable. This hypothesis will be described considering diverse user groups ('Digital Natives' vs. 'Immigrants'). [5]

The findings from both sections, literature based and empirical, are believed to be also relevant for classic products like cars, machines, consumer electronics, etc. Even if these products employ physical interfaces, the implications of physical affordances vs. symbolic abstraction are transferable. In the age of digitization and diminishing mechanical constraints, the expected learnings are believed to be relevant for product design education. In order to understand the current shifts in interface design and to introduce to the related discourse, it is necessary to review some classic topics of human computer interaction and interface design. First, the concept of *metaphor,* which had been discussed thoroughly in the 1980s and 1990s. [6, 7] Second, the concept of *affordance,* which has played a key role in the discussions about self-explanatory easy-to-learn products since the late 1980s. [4] And third, the concept of *digital native* users, which surprisingly had been introduced already over a decade ago [5] and needs to be updated today. In the last part of the paper, a concise empirical study will be presented on how the subjective perception of iOS6 and iOS7 has changed during the eight months since the presentation of iOS7.

## 2 METAPHORS

Physical artefacts can often be understood by merely looking at them. We are capable to figure out how a mechanism works by exploring it with our eyes, depending on previous knowledge and experience we see possibilities to move, press, or turn, and we know and recognize mechanical constellations that restrict these possibilities. This does rarely happen when we look at digital equipment. A look into the hardware does not easily tell if we are dealing with a GPS-tracker, a mobile audio recorder, or a control unit for heating systems. Even if a look at the digital statuses and processes inside the silicone modules was possible, it would not be meaningful for us – meaningless zeros and ones. To overcome this problem, 'humane' interfaces were invented, which are all based on language and (visual) metaphors.

The big era of the metaphor in computer interfaces began when the first affordable pointing device – the 'mouse' – and enough computing power for a graphical display was available. Now the transfer of real life concepts to the computer screen had become technically feasible. In the late 1970s and early 1980s a new visual interface paradigm imitated the real life context of the new target audience: the office. Until the 1970s only specialists could operate computers. Now 'simple' office clerks and secretaries were to use them. To lower the cognitive effort and cost of learning, familiar items where imitated: a desktop, files, folders, and waste paper baskets. [8]

A second wave of real life metaphors became fashionable with the 1990s 'multimedia' interfaces. Driven by the upcoming World Wide Web, computer games and multimedia edutainment, the computer started to migrate into home offices and living rooms. Again metaphoric approaches were used to facilitate computer use for everyone. Microsoft even developed a Windows substitute based on a visual *living-room* metaphor (Microsoft Bob). [9] The idea behind this approach is, simply put: Give inexperienced people what they already know: Office people get an office interface, users who use a personal computer in their free time get an living-room interface. Still the approach failed this time, because the desktop metaphor had already been internalised by too many users – and it simply fits better to most of the activities and functions offered by a computer at that time.

Until Apple introduced the iPhone in 2007, the discussion about the pros and cons of strong real life metaphors stagnated. Still, there had been a continuous discourse about if and how to move interface design 'beyond the desktop'. However, simply rebuilding the physical world in interfaces was hardly considered an innovative option anymore. Along with the multi-touch interaction paradigm, Apple then revived the idea of transferring knowledge from the real to the digital world and resumed the discussion about metaphors. Very similar to Microsoft Bob, books on the iPhone and iPad looked again like real books with stitched leather covers stored in wooden shelves, calendars showed chrome plated spiral binding, and so forth. [10]

## 3 AFFORDANCE

As said at the beginning of the section about metaphors, we often figure out what an object allows us to do with it, by mere visual exploration. Based on experience with other objects in our environment, we learned about the laws of physics, mechanics, and about relations between our body and the things that surround us. Seeing a gap or a hole, we directly 'see' for instance if we would be able to insert a fingertip or only a fingernail. Gibson, a cognitive psychologist, coined the term *affordance* to describe this relation between a subject and an object. [4] Even earlier, these self-explanatory functions had been described as *indicating signs* in German product design theory [11], and in the product semantics approach [12]. These *designed* affordances (from the designer's point of view), or *perceived* affordances (from the user's point of view) can also be understood as *micro-metaphors*. Whereas for instance music software often imitates a recording studio and its equipment on all levels – workflow, spatial layout, interaction patterns with modules like mixers and effects, and colours and materials – the design of affordances only employs basic physical and mechanical rules. The orientation of the groove of a slider for instance clearly indicates in which direction the slider can be dragged. To do so, a photorealistic rendering of a brushed stainless steel slider is not necessary. To communicate the mechanical restriction to only one direction a simple black and white representation will suffice.

Along with visibility, consistence, and feedback, creating *artificial affordances* used to be considered one of the key factors for self-explanatory, easy to use interfaces. [12] Following this theory, buttons indicate their 'clickability' by a bevel effect and for instance a ribbed surface indicates the 'dragable' corner that allows resizing a window. Both of these examples make use of moderate 3D-effects to create the desired affordances. This explains why the interface design community has been engaged in a heated debate about the trend towards *flat* design. To put it in simple terms, the main argument of the critics of flat design is: Without 3D-effects there are less affordances, therefore the interface is less self-explanatory, and the result is bad usability.

## 4 CHANGING USERS

In 2001 Prensky introduced the term *Digital Natives* to describe a new generation of users who 'have spent their entire lives surrounded by and using computers, videogames, digital music players, video cams, cell phones, and all the other toys and tools of the digital age'. [5] While a lot of Prensky's claims are still valid today, some of his examples for the Native/Immigrant-divide show their age of more than a decade. In 2001 a Digital Native grew up using a cell phone. Today using a cell phone with hard keys is considered digital *naïve*. Today's Digital Natives use smart phones that combine all the different gadgets Prensky mentioned in a single mobile multi-touch device: 'computers, video-games, digital music players, video cams, cell phones'.

Anyone who ever saw a two-year-old child using an iPad can anticipate that a new generation of Digital Natives is on its way. However, also today's Digital Immigrants are different then ten years ago, they are a much more heterogeneous group than in 2001. There are those who were driven out of their analogue world by force – due to changes in their professional environment or by social peer pressure, and there are the ones who immigrated eagerly, attracted by the promises of the new digital world. Furthermore, a lot of today's Digital Immigrants have been immigrants for more than two decades now, so their 'analogue accent' becomes weaker and weaker. For them, a double click may feel already more 'natural' than cracking a nut or peeling an orange.

For both types of users, the second generation of Digital Natives and the assimilated Digital Immigrants, the idea that interfaces are being learned by transferring knowledge from the 'real' (i.e. analogue) world to the digital world may loose its dominance. Experienced Digital Immigrants rather transfer knowledge they previously acquired using *other* interfaces, as opposed to employing knowledge they acquired interacting with the physical world. [13] Children today learn and grow up in both worlds more or less *simultaneously*, which makes a strong and obvious metaphoric transfer between these worlds obsolete. But will it also make the small-scale metaphors behind designed affordances obsolete? Will a flat button do the same job as a bevelled one for second generation Natives and assimilated Immigrants?

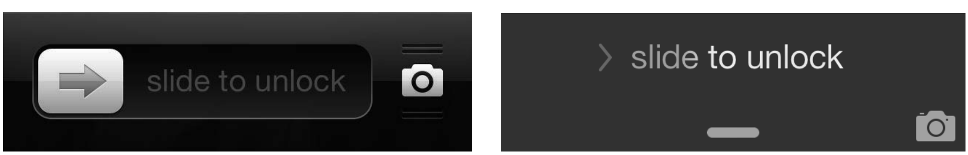


*Figure 1. Old and new sliders of the unlock screen of Apple's iPhone: Strong affordances based on physical micro-metaphors (left). Weak affordances by only an arrow and a left to right animation effect (right)*

## 5 FLAT DESIGN VS. SKEUOMORPHISM

A skeuomorph, as defined by the Oxford Dictionary, is 'an object or feature which imitates the design of a similar artefact made from another material', or for the domain of 'computing': 'an element of a graphical user interface which mimics a physical object'. [2] The term had been used in archaeology for more than a centennial to describe for instance residues of typical forms of metal vessels found in copies that were made of clay instead of metal. [14] Recently the term 'skeuomorph' was frequently used to discredit Apple's design approach for mobile devices and its imitations of stitched leather, wooden shelves, etc. Traditionally, the esteem of imitations and fakes is not too high in the design community. Therefore, it came at no surprise that parts of the interface design community celebrated Microsoft's new version of *Windows Phone* in 2010, which was designed in a visually consequent flat

and abstract style, reminding of classic (Swiss) typography. It is devoid of three-dimensional effects like bevel, emboss, or drop shadows, and it refrains from citing material of the physical world. Put positively, it solely employs solid colours and clear typography. However, also abstract interfaces like Windows Phone are based on citations originating from the non-digital world - in this case the source is the typographic style of the 1960s, as well as classic airport signage and guidance systems. [15]
Whereas the use of faux leather and wood in digital interfaces can be considered as *kitsch*, the idea that there could be anything like 'authenticity' or 'honesty' in the design of digital interfaces is, strictly speaking, absurd. [15] There is no way of designing an interface appropriate to any material. Anything seen on a digital screen is based on metaphors and conventions. What might be perceived as a genuine digital look is the result of a long history of contingent design decisions that formed a visual tradition. These stereotypes of the digital world are reproduced regularly in Hollywood movies, where for instance password screens (to cancel the countdown) cite interfaces of the 1970s, displaying green type on a black screen.

## 6 SURVEY ON IMAGE ATTRIBUTIONS

After Apple presented a preview of its 'flat' mobile operating system iOS7 on 10 June 2013, the author carried out a first survey only three days later, in order to document the very first impression the new interface design evoked. The same study was repeated eight months later, in order to document if and how images and attributions of both the old and the new interface have changed over time. The studies were to provide insights on how users of mobile devices adapt to a rather radical redesign measure and how the perception of the two interface versions changed after eight months of exposure to the new iOS. After the survey informal discussions were held in order to gain insights that would help to analyse and interpret the results. Both surveys used the same semantic differential to sample associations attributed to both the new and the old interface. The bipolar pairs, polled on a five point scale, were:

- professional – amateur
- cheap – expensive
- serious – fun
- finished – unfinished
- happy – sad
- grown up – childlike
- loud – quite
- dynamic – calm
- tactile – not tactile
- natural – artificial

Before the questionnaires where distributed, screenshots of iOS6 and iOS7 where displayed by a projector. Both surveys where conducted in regular classes of a Bachelor and Master program in Business Communication Management. In the first survey 34 students took part, in the second 69 different students of the same program in the same semester. Age was between 19 and 42, with a median of 27 years. Only 24% of the participants were male. Hence, social background, age, and gender distribution are far from being representative for average population. However, the fact that the participants' smart-phone use is clearly above average leads to higher relevance in the target group of smart-phone users: 91% of the participants owned a smart-phone (49% an Apple iPhone). Only 9% use a classic cell phone with hard keys.

## 7 SELECTED RESULTS

The informal discussions after the survey revealed some unexpected connotations of the terms used in the semantic differential. Usually this can be realised and avoided by conducting a pre-test, which in this case was not possible, because the goal was to preserve the impression the participants had after they saw the new iOS for the very first time. The parameter 'cheap – expensive' was intended to relate to the look-and-feel of the interfaces. However, the discussion revealed that many participants confused interface and overall brand, stating that 'Apple is always expensive'. Also the 'finished –

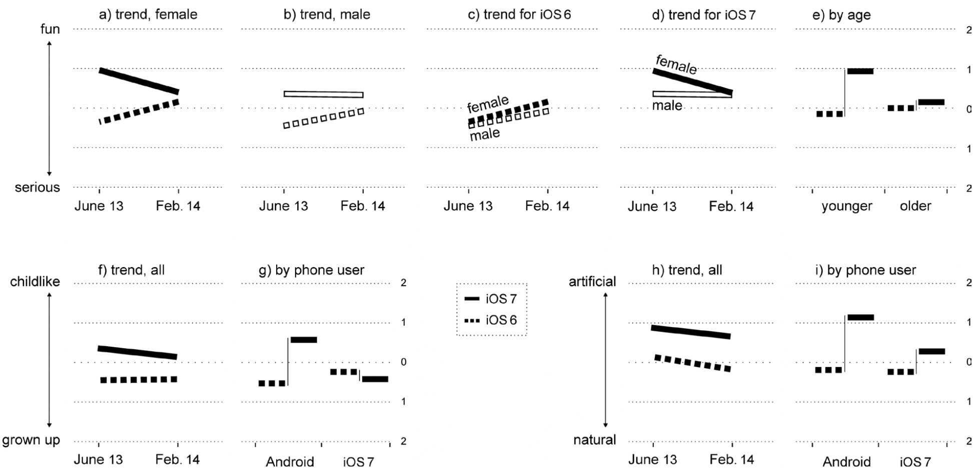


*Figure 2. Trends and differences in attributions to iOS6 (dotted) and iOS7*

unfinished' pair was not understood in the intended sense. Again it was intended solely as a description of the look of the interface, the discussion revealed that 'finished – unfinished' was often confused with product age. Then the evaluation of the questionnaires revealed that often the pair 'tactile – not tactile' had been skipped. Obviously a lot of the participants had problems understanding the meaning of 'tactile' in this context. This is why the mentioned parameters were not used in the results.

Unsurprisingly, in both surveys the very colourful iOS7 was attributed more 'fun' and 'childlike' than the skeuomorph iOS6. Correspondingly, iOS6 was rated more 'grown-up', and 'serious' (see figure 2 a and f). Whereas older students (aged 27 to 42, median = 29 years) do not see too much difference between the two versions of iOS, the younger students (aged 19 to 26, median = 23 years) rate them more extremely different (see figure 2e). After only eight months, the novelty effect already seems to wear off: The new iOS7 drifted towards 'serious' and 'grown up', and the old iOS6 was rated more 'fun' than before (see fig. 2a and f). This trend is even stronger in the female part of the participants. In the male part only the old iOS6 moved from clearly 'serious' towards more 'fun', whereas the perception of iOS7 almost remained unchanged (see fig. 2 a, b, c, d).

Also subjective expressions of opinion were stronger in the informal discussion after the first survey: 'too garish and loud', 'looks like a toy', etc. In a smart-phone context a 'fun – serious' scale does not have a clear positive – negative connotation. However, 'childlike – grown up' does have positive – negative implications. It comes to no surprise that the iOS7's rating as rather 'childlike' stems mainly from Android users, whereas iOS7 users rate their operating system of choice even a bit more 'grown up' than the old iOS6 (see fig. 2f and g).

As expected, the abstract and 'garish' iOS7 is rated more 'artificial' (see fig. 2h), whereas iOS6, which cites natural material like wood, leather, and felt, is rated more 'natural'. However, both surprisingly show a trend towards 'natural'. In the case of iOS7 this might be due to a habituation effect. The users simply got used to the vibrant colours. An interesting fact is that Apple and Android users rate the old iOS6 almost equally neutral (between 'artificial' and 'natural), whereas they rate the new iOS7 more extremely different (see fig. 2i, which shows an average of both surveys by user type). This is probably due to the rather negative connotation that 'artificial' has today (compare: 'artificial flavour' vs. 'natural grown'). Therefore Android users will rate an Apple OS more easily 'artificial', i.e. in a negative way, whereas Apple users will want to avoid negative connoted ratings – even if they actually like the 'artificial' look.

## 8 CONCLUSION AND OUTLOOK

Of course a survey based on subjective impression does not produce any knowledge about the actual learnability or usability of the examined products. This could only be achieved in a more objective way by user testing. Still, the clear trend that iOS7 becomes more accepted as a 'serious' and ‘professional’ tool over time is revealing that the subjective attributions may be disconnected from factual usability. Another interpretation is, that affordances based on physical micro-metaphors are not needed anymore, because a majority of the users have been using iOS6 for several years and do not need metaphoric-physical hints anymore, for instance to find out how to unlock an iPhone. The ‘unlock-slide’ has become a well-trained habit. Even non-iPhone users have seen this interaction pattern so often that the flat and typographic interface works fine – in spite of its lack of affordances. The matter seems to be too complex to come up with clear and simple recommendations – like which approach is more suitable for which target audience. However, it seems probably today that also the long-term trend will lead towards abstraction, especially when we consider that digital natives are introduced to today’s digital world almost simultaneously with the physical world. One decisive question will be, if there will be enough Digital Naïves and early Immigrants left when the next interface paradigm change will come. Then, interface design might again ‘fall back’ into using real life metaphors to attract new users – just like it did when GUI emerged in the 1980, with Multimedia in the 1990s, and when Multi-Touch was popularized in 2007. We might discuss this further at E&PDE 2025.

Concerning product design education, the topic should be covered more intensively, for the continuing digitalization unavoidably leads to a loss of physically determined indicating signs. Even in classic product domains, we are confronted with interfaces that are completely detached from mechanics and physical coupling. Even physical controls like a car’s steering wheel, and the accelerator and brake pedals have technically become mere digital input devices. In the case of the steering wheel, tradition constitutes a strong argument. But in many other cases, like radio or heating controls, we have to discuss with what kind of signs operability and use patterns can be communicated in future.

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# SUPPORTING THE STEM TRANSITION BETWEEN SCHOOL AND UNIVERSITY

**Avril THOMSON, Phillip SAYER, Andrew McLAREN and Derek LITTLE**
Faculty of Engineering, University of Strathclyde, Glasgow, Scotland

**ABSTRACT**
This paper sets out to review the relationship between Schools and Universities in the West of Scotland with the strategic aim of widening access to STEM (Science, Technology, Engineering and Mathematics) based subjects. With the changing nature of education in Scottish schools because of the Curriculum for Excellence and the requirement for increasing, the number of students who participate in STEM subjects at university. An eight-person research team was assembled at the University of Strathclyde to investigate, support and raise awareness of the key factors affecting successful STEM transition from secondary school to university. The group made up from students and academics was a novel approach and aimed at developing their knowledge of the current Scottish education system whilst developing partnerships with secondary schools in the local Glasgow area.
Several peer discussion groups were conducted as part of the methodology and it was through these that ideas, such as a student elective scheme allowing university students to enter schools and run project based learning workshops, could benefit the transition strategy for young people to enter the STEM based disciplines at university. The outlined proposals, when implemented, have the possibility of negating the previous inconsistency of previous attempts to address the problem of successful STEM transition. Four key project deliverables were identified that had the potential to develop the strategy necessary to encourage and develop school pupils into the STEM subject areas and with the help of staff and pupils, the researchers were able to identify potential ideas and solutions to facilitate this.

*Keywords: Transition, school, university, STEM, widening access*

## 1 INTRODUCTION AND BACKGROUND

The UK and in particular Scotland there is a lack of students continuing into higher education within the STEM based subject areas. This is of note in the Glasgow area of the Scottish education system, which has recently changed to the new Curriculum for Excellence (CfE) system [1]. The CfE aims to provide pupils with the skills for learning, life and work; although the potential benefits of the new system have clearly been outlined by the SQA there remains a lack of clarity about certain associated details, such as the effectiveness of a broad general education (BGE) in preparing pupils for senior phases of secondary education. Issues of this manner have a direct impact on the progression of young people's learning and consequently their advancement and suitability for higher education [2].
In order to address this situation an eight person team was assembled from across the faculties of Engineering and Science with the aim of exploring ways of designing and developing links between local schools to encourage, support and enhance the pupils awareness and appreciation of STEM activities. The research team conducted a literature research into CfE, met and discussed all aspects of the problem with teachers and pupils in local schools. The resulting output from these findings, proposing activities and ideas generated would potentially improve the STEM transition from school to university. The secondary schools that participated in the project were Eastbank Academy, Govan High, John Paul Academy and Smithycroft Secondary all local comprehensive schools. A brief partnership with Glasgow Academy a private fee paying school was established which provided diversity in data collection and enabled the researchers to draw comparisons between government and independent schools. This proved to be an extremely valuable experience and contributed significantly towards the aims of the project. With the help of staff and pupils in the schools, it was possible to identify potential ideas and solutions to the four key project deliverables the researchers identified at an early stage. These included:

- Ensure staff at school and university understand the key factors involved in successful STEM transition
- To prepare a specification for pre-university material to support STEM activities
- Investigate the potential and feasibility of summer schools
- Outline student led mentoring for university students

The research team who conducted the detail of the research came from a wide range of backgrounds and educational routes. Because of this, the backgrounds and experiences of the researchers provided yet another valuable source of information through peer discussion groups and reflection upon personal experiences [3]. Under the guidance of researchers' supervisors, the project has successfully identified key factors that would contribute to successful transition and generated potential ideas for implementation. There were a number of key stages in this project. Initially background research including literature, interviews and school visits was conducted to identify the main requirements. Requirements were then captured in a specification allowing solutions to be generated and evaluated and clear recommendations to emerge. Each of the main project phases are presented in the remainder of the paper.

## 2 BACKGROUND RESEARCH

### 2.1 Introduction

A literature review, semi-structured interviews and questionnaires were carried out to capture data relating to CfE (Curriculum for Excellence), current practice in schools, understanding stakeholder requirements (pupils, parents and teachers) and existing relevant STEM initiatives and events.

### 2.2 Curriculum for Excellence (CfE)

At present, schools and universities appear to have a lack of clarity about the details associated with CfE. A key part of the research process was to investigate CfE, identifying strengths and weaknesses and consequently ways in which pre-university material could aid teachers without adding to their already increasing workload [1],[4]. From the research conducted in to the curriculum for excellence table 1 below depicts the year differences, which the majority of school pupils will follow during their period in a Secondary School education programme.

*Table 1. Comparison of educational achievement*

| **Year** | **S1** | **S2** | **S3** | **S4** | **S5** | **S6** |
|---|---|---|---|---|---|---|
| **Old System** | General Education | General Education<br><br>Choose Subjects | Standard Grades | Sit Exams<br><br>Foundation/Access 3<br>General/Intermediate 1<br>Credit/Intermediate 2 | Sit Credit/ Int 2/ Highers | Sit Higher: Advanc Higher: |
| **New System** | Broad General Education (BGE) | BGE | BGE<br>Choose Nationals/Highers | Only National 5/ Higher examined externally<br>National 3<br>National 4<br>National 5<br>New Higher | Sit National 5/ Highers | Sit Higher: Advanc Higher: |

As can be viewed from the analysis the new curriculum places less emphasis on assessment and a fact filled curriculum and more on "skills for learning, life and work" and interdisciplinary learning. In practise, this means that students will choose subjects a year later and in some cases may only face exams in 5th year. Also, whilst the new Higher graphic communication, engineering science, mathematics remain similar to the old Highers in content - physics is the exception with the introduction of new topics such as space and relativity into the syllabus – more teacher discretion will be required in assessment and there will be greater room for projects and investigations. The latter will provide scope for cross-curricula skills based learning [4].

The interviews conducted by the researchers from the schools highlighted strengths and weaknesses in the CfE and this would help the design of the recommendations to promote STEM success through to University level.

**Strengths:**

- Good skills development and increased proportion of project based work.
- Students not rushed to perform at a new level. There is more freedom and time to work with each student's level of ability.
- CfE construction allows more pupils to gain qualifications.
- National 4 may suit many more peoples with a better balance between learning and assessment.

**Weaknesses:**

- Lack of rigour in primary school combined with BGE in secondary is failing to prepare students, which may restrict the possibility of students attaining Highers where a lot of foundation knowledge is required (e.g. Maths).
- Some felt that CfE would not sufficiently push the more academic pupils. Whilst more pupils will pass exams and get qualifications, the standard of achievement may decrease.
- National 4 courses will be assessed by teachers through coursework assessment and not externally assessed. This may lack credibility. It is possible to pass a National 4 without knowing the basics of a subject.

The research conducted indicates that the new curriculum will be beneficial to STEM subjects in instances where there is more practical and project work since this will allow students to see their subjects from a hands-on point of view. The new practical approach will demonstrate to the student the practical application of physics and maths solves problems, therefore, giving pupils a greater contextual understanding. It would also appear that there is more room for pupils to undertake the curriculum at their own pace and even sit more advanced subject levels in 4$^{th}$ year rather than 5$^{th}$ or 6$^{th}$ years. Unfortunately, a skills based approach also means that inevitably pupils will not have the same depth of knowledge and understanding. For STEM university/college degrees, a significant amount of foundation knowledge is required [5] and the new curriculum may not provide this sufficiently. There is a real concern over the level of numeracy pupils will attain in primary and as part of BGE in secondary. Even at National 4 level, rigour may be lacking in courses, which lack externally assessment. Academic high achievers could "coast" to through secondary education if left unchallenged.

## 2.2 School Visits

Before schools closed for the summer holidays several school visits were initiated to Govan High School, Smithycroft Secondary School, John Paul Academy, Eastbank Academy and Glasgow Academy. In addition correspondence with Westhill Academy, a school in Aberdeenshire with strong links to the oil and gas sector contributed to findings. Two questions were asked in each school, a summary of responses are shown below:

***How do the schools currently promote STEM subject?***

- Former Students make occasional visits.
- Individual teachers can be a source of inspiration.
- Money Week alongside the Credit Union.
- Leadership program (Individual project for senior pupils).
- Future Skills Day – a day of fun workshop with industry and educational establishments.
- Science and music project (Paragon Ensemble and Glasgow University).
- Industrial visits to school e.g. BAE systems.
- Field trips e.g. Shipyard visits.
- One-off design projects e.g. Rocket Design.
- After school clubs e.g. Science Club.

***What current links do the schools have with the schools, Colleges and Universities?***

- None in some cases – sometimes they rely on pupil initiative and principal teachers.
- Anniesland, Stow & Glasgow City College – Skills for Work and Electrical Engineering scholarship.

- Strathclyde University to provide UK Maths Challenge.
- Strathclyde Naval Architecture Department.
- Space Programme with Glasgow University.
- Aileen Hamilton (STEM Ambassador for West of Scotland) helps to promote STEM subjects within the school.

Discussions with staff and students in each school focussed on how the university could best engage and support schools in STEM. A common finding was the need for pupils to have their imagination challenged through workshops and activities. Running problem solving, maths and engineering workshops with current university students would not only challenge pupils through new educational approaches but it would also provide school pupils with an insight to the life and expectations of university life through their interaction with students. Engagement of this nature was of strong importance for the teachers, as it would provide an example of aspirational leadership through engagement and inspiration. Modern ideas were another common theme. Schools were keen to encourage the study of STEM subjects through examining current technologies such as mobile apps. Another key initiative suggested was school pupils could visit university and experience up to date technology such as prosthetics labs and 3D printers in DMEM.

In conclusion, it was apparent that university schemes and STEM projects have found consistency and long-term sustainability difficult to achieve in schools. One-off projects seem to occur on a semi-regular basis; however, it is difficult to create lasting partnerships and initiatives. In the midst of CfE it is perhaps even more difficult to create links with schools given teacher's increasing workloads and limited time. On the other hand, teachers did indicate that pupil engagement via workshops would have potential and relate well to the skills based cross curricula learning at the heart of CfE. Given these findings, the team established four broad deliverables that would create the STEM learning and support structures required. The deliverables contain a series of ideas that add different value to achieving the goals of the research. An overview of each of the deliverables is in the following section.

## 3 REQUIREMENT CAPTURE AND SPECIFICATION

Project deliverables were revisited to focus and prioritise key requirements:

- **Deliverable 1,** involved widening Access to the STEM subjects to "ensure staffs at schools and university understand the key factors involved in successful STEM transition".
- **Deliverable 2,** main purpose was to prepare a specification for pre-university material to support STEM activities.
- **Deliverable 3,** implementation of a Summer school activity. By attending summer schools, the pupils can gain a vital insight into studying at University and University life in general. This deliverable focuses on improving the transition between school and university by providing extra academic support and essential university skills for school pupils who could potentially struggle in their first year of university.
- **Deliverable 4,** develop a Student mentoring programme in order to give students a helping hand at all times. The mentoring programme enables a successful, highly motivated student from the year above the mentee to be trained in the programme and then placed as a mentor for one of the students in the year below them, 1st year. As the student progresses they will be expected to do the same for the years below and keep the cycle going.

The research team began speaking to schools about the four deliverables and assessing what teachers and pupils required to improve STEM transition and support i.e. what were their priorities. The conclusion reached was to join deliverables one and two since both provide a powerful solution when integrated together. Deliverables 3 and 4 were more of a long-term solution and while important to the overall structure both and would be developed and implemented later.

A list of specifications for each of the deliverables was generated to facilitate brainstorming of solutions to meet these conditions. Ideas generated from the brainstorming session were then analysed and assessed against the set specifications. The key specifications used to evaluate the deliverable ideas against are as follows:

- ***pupil engagement*** **:** must be geared to motivate and inspire students
- ***time:*** must be relevant to the world today and not require a huge investment of time

- ***feasibility:*** create a solution that is practical and inclusive of all schools irrespective of current progression to higher education
- ***innovation:*** must give a positive and realistic view of university life in STEM subjects
- ***sustainable:*** capable of building and sustaining strong links
- ***teacher effort:*** be easy for teachers who already have a lot of commitment to implement

## 4 SOLUTION GENERATION AND EVALUATION

Team brainstorming generated 11 ideas of potential solutions across both deliverables:

**Deliverable 1:**

- Booklet for Staff
- News Bulletin
- Teacher Evening at University

**Deliverable 2:**

- App Software
- Student Elective Class
- Booklet for pupils
- Film
- Request Box
- Apprentice Challenge
- Lunch/After School Club
- Year-Long School Project

Evaluation of ideas was then carried out. The team split into small groups and listed the positives and the negatives of each individual idea. This process highlighted any flaws and future issues that could develop. The next stage was to put the ideas into a matrix this would show the top few ideas, as there are too many ideas to implement them all. Table 2 shows the scales used whilst table 3 shows matrix classification system.

*Table 2. Idea Evaluation Scale*

| Scale 1-5 | 1 is Negative | 5 is Positive |
|---|---|---|
| Sustainability | Short | Long |
| Timeliness | Long Time | Little Time |
| Innovation | Not | Very |
| Teacher Effort | Lots of Effort | No Effort |
| Feasibility | Hard to do | Do-able |
| Pupil Engagement | Not | Very |

*Table 3. Evaluated Ideas from Deliverables 1 & 2*

| Ideas from Deliverable 1 & 2 | Sustain-ability | Time | Innovation | Teacher Effort | Feasibility | Pupil Engagement | Total |
|---|---|---|---|---|---|---|---|
| **App Software** | 4 | 3 | 5 | 5 | 2 | 3 | 22 |
| **Student Elective Class** | 5 | 2 | 5 | 3 | 2 | 4 | 21 |
| **Booklet for pupils** | 5 | 4 | 1 | 4 | 5 | 1 | 20 |
| **Film** | 2 | 1 | 3 | 5 | 4 | 3 | 18 |
| **Request Box** | 4 | 2 | 3 | 2 | 4 | 3 | 18 |
| **Booklet for Staff** | 5 | 4 | 1 | 2 | 5 | 1 | 18 |
| **News Bulletin** | 5 | 2 | 3 | 3 | 4 | 1 | 18 |
| **Apprentice Challenge** | 3 | 2 | 3 | 2 | 3 | 4 | 17 |
| **Teacher Evening at University** | 3 | 2 | 4 | 1 | 3 | 1 | 14 |
| **Lunch/After School Club** | 3 | 2 | 3 | 1 | 3 | 2 | 14 |
| **Year Long School Project** | 2 | 1 | 3 | 1 | 2 | 5 | 14 |

## 5 CONCLUSIONS, RECOMMENDATIONS AND FUTURE WORK

The research group recommended that the key factors derived from this investigation was to maintain consistency with the schools; pupils must be engaged; to develop and run more engineering oriented activities; finally enable pupils have a clear understanding of University and Engineering practices.

In conclusion, the most successful idea was the app and this was popular because it uses technology to present STEM information. However, the student elective class would provide the most sustainable method of information deployment and the team felt that the student elective class had all of the best interactive ideas included. It also gave students an incentive to complete it and do it well. At the same time, it would help teachers understand the key issues involved with STEM transition since they would be present while the class workshops were taking place.

The research team felt the Student Elective is likely to be the most successful, innovative and sustainable idea since it ensure both university and school staff have insight to the factors involved with successful STEM transition. It promotes STEM subjects to school pupils in an interactive environment and gives University students the incentive to be involved because they are able to gain credits toward their degree. The Student Elective also has the potential to establish strong links between the university and Glasgow schools in a way that will be consistent and long term.

To prove that the selection process is sound the university are currently running a pilot Elective Class which commenced in February 2014. Five MEng students are enrolled in the class and are engaging with 2 local secondary schools. Findings from the pilot study will inform future expansion and roll out of the initiative.

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# ENHANCING STUDENT MOTIVATION – 'RAISE THE BAR'

**Anders HÅKANSSON and Peter TÖRLIND**
Division of Innovation & Design, Luleå University of Technology, Sweden

**ABSTRACT**
The quest for enhancing student motivation, commitment and performance in higher education is an ever-present struggle for university teachers. Of course, the hunt for a good grade is something that is very central for students, but as a teacher you would like to reach further and find a deeper, more personal motivation within each student. A hypothesis that was investigated was that students will accept high demands if they are clearly defined and presented directly in the beginning instead of being introduced gradually during the course. In the present course, a team of six teachers was put together in order to be able to handle the students' need for coaching and support. The course included multiple sub-deadlines concluded by status presentations, called Design Reviews, where the groups updated the teaching team and other groups on the project's progress. The Design Reviews included both an oral presentation of five minutes and a written memorandum, called PM. Each student was responsible for one oral presentation and one PM. Examination of the course was based on the final project result as well as on performance during the Design Reviews. The conclusions from this approach are that the general motivation was increased. The project results were very good and included several innovative solutions. Student reaction to the high demands was positive but teacher coaching is a very important factor for keeping this on a manageable and stimulating level for the students and preventing it from being an oppressive stress factor.

*Keywords: Motivation, commitment, coaching, expectations*

## 1 INTRODUCTION

This paper describes a study made to investigate how raised demands/challenges and more formalized coaching would affect student motivation. Felder and Brent [1] argue that a necessary condition for students' intellectual growth is challenge; however, this challenge should be adapted to their current development level. The study took place during a project course for the third-year students at the Industrial Design Engineering program at Luleå University of Technology, Sweden.

The quest for enhancing student motivation, commitment and performance in higher education is an ever-present struggle for university teachers. Teachers constantly develop means to try to bring out the full capacity of the student. Motivation is a substantial subject, and researchers seem to agree on three basic aspects of human behaviour involved with motivation: to choose a particular action, to persist with that action, and to put effort into that action [2]. This implies that, in order to facilitate this theory, the goals and purposes are made clear to the students (and adapted to the students' current development level) or, rather, that the students identify the goals and purposes. One must understand that students in most cases carry more than one goal and that these goals interact, both positively and negatively, in each given situation [3]. It is therefore important to place the course goal in question in a context meaningful to the student. It is also of great importance to understand the students' underlying goals in order for a teacher to provide the most effective coaching. Research has shown that informal contact between students and faculty can influence student persistence positively [4], [5], [6].

Kolić-Vehovec et al. [7] identify four different types of goal orientation among university students and the learning strategies among these four types differ regarding goal orientation, perceived effort engaged, reading strategy, and the like. Placing different types of goal-oriented students in the same project group implies conflicts and difficulties to cooperate within the group. Taylor et al. [8] emphasise that to that successful learning experiences for capstone design teams require faculty to shift their role from a traditional lecture or consulting role to a coaching role. Coaching has been used in sports for a very long time and is used more and more in professional work and education. Bresser and Wilson have put together four examples of definitions of 'coaching' [9]:

- 'Unlocking a person's potential to maximize their own performance. It is helping them to learn rather than teaching them' [10].
- 'A collaborative, solution-focused, results-oriented and systematic process in which the coach facilitates the enhancement of work performance, life experience, self-directed learning and personal growth of the coachee' [11].
- 'A professional partnership between a qualified coach and an individual or team that supports the achievement of extraordinary results, based on goals set by the individual or team. [12].
- 'The art of facilitating the unleashing of people's potential to reach meaningful, important objectives' [13].

These definitions emphasize the development and growth of the individual's potential and the achievement of a deeper understanding for the task at hand. Coaching can have a big impact on team performance, Taylor et al. [8] presented four key indicators of successful design teams in which two where related to the coaching – 'Coach awareness of team success and the coach ability to assist in both team and design process'. Taylor et al. [ibid.] also found that one activity of successful teams where their ability to prepare for and reflect on design reviews an activity where the coaches played a large part in helping teams prepare for and reflect on periodic reviews. In this study, much effort was put into goal definition and goal positioning together with substantial resources regarding available coaches.

## 2 COURSE CONTEXT

This study was initiated to investigate the benefits of changes made to the layout and work methods in project courses at the program for Industrial Design Engineering at Luleå University of Technology. Traditionally, the projects are carried out with very few restrictions and much responsibility on the students [14]. Advantages with this approach are mainly real-life contact with industry for the students and the possibility to run a project on their own. Disadvantages are that group projects tend to have students keeping in the background, not contributing to the group and a tendency for less work in the beginning and more and hectic work at the end. Few involved teachers in the projects results in high workload for teachers with less possibility of in-depth feedback. To overcome these disadvantages a new layout was proposed and implemented in the course A0013A, Product and Production design.

The course A0013A, Product and production design, (7.5 ECTS) is a course in integrated product development for third-year students in the Industrial Design Engineering program (300 ECTS master's program), focusing on the interaction between product design and production design. During the course (10 weeks) students start from an existing product with the aim of developing and improving it based on a user perspective, in terms of design, ergonomics, durability, and manufacturing. In this course the students are for the first time presented with a vague design problem, previous project courses has often had a fairly detailed design brief with a clear intention, requirements and goals. In this project the problem was wicked or ill-defined [15] and it was up to the students to understand which users the product was intended for, their needs and requirements. The human centred design approach is present in all stages from the pre-study, where e.g. observations and interviews aims to capture the users point of view on the product at hand, to the production design, where not only suitable manufacturing techniques are investigated but also the plant layout is designed with regards to logistics, safety and worker comfort. The course is carried out in project teams that are provided with coaches from the teaching staff. To further support the coaching function, more teachers were engaged in this course compared to previous ones in order for each coach to be able to provide the in-depth and individual feedback needed. The course uses an approach where market research, product development and manufacturing are accomplished in parallel. The design of the new product also includes materials and production choices as a natural part of the innovation process. The course does not include new theory, but instead draws upon the theory, knowledge and practice from previous courses. The teaching team has designed a stage-gate based framework on *what* to deliver; *how* this is achieved is up to the student teams. Given the nature of creative work a structured approach with checkpoints and intermediate goals reduces uncertainty and creates structures for ill-defined problems [16, 17]. The course framework is a simplified design process with five phases. After each of the four first phases a design review (DR) is done, during which the students present the results in an oral design review and with a short written report (PM). In the end a longer presentation is held, during which the students present their final product (including how it will be produced) and deliver the final documentation. See Figure 1.

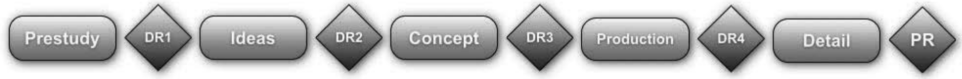


*Figure 1. The framework of the course with four design reviews*

During each DR, the students receive feedback from the whole teaching team as well as feedback on the written PM from their coach. The coaching team tried to create an environment where students had to present their results and conclusions and also the underlying rational (i.e. knowledge and arguments that form the basis for these results – '*Why have you selected this material? Why is this important? Why is this concept better?*'). This type of critique forced the students to reflect over their own decisions and conclusions. Feedback was very clear and direct, which can seem harsh at first but which the students appreciate more towards the end of the course.
To ensure that the different coaches assess the work in a similar and objective way, grading templates are used throughout the course. An example from the oral presentation is found in Table 1 (grading is done using a graded scale where 3 is pass and 5 is pass with distinction).

*Table 1. Grading template for oral presentation*

| | |
|---|---|
| **3** | Construct coherent arguments and articulate ideas in an acceptable manner, does not feel well-rehearsed Content is acceptable. Means of communication is acceptable. |
| **4** | The presentation was performed in a good and steady pace, and the content is highly relevant and feels rehearsed. Means of communication in the form of pictures, models, visualizations are used well and show good design that is clear, well designed, and structured. |
| **5** | Presents a convincing show of good design, argument is clear and logical, and contains the design rationale for choices and decisions. Answers questions quickly with honed and logical arguments. |

In the design process students are encouraged to explore the different concepts by experiments and prototypes, this experimentation takes time and one of the most important parts is to selecting the right prototypes. Houde and Hill [18] highlights *'...Prototypes provide the means for examining design problems and evaluating solutions. Selecting the focus of a prototype is the art of identifying the most important open design questions'*.

## 2.1 Relation to learning outcomes for Industrial Design Engineering

The examination goals for Swedish higher education are regulated in Sweden by Universitetskanslersämbetet (UKÄ); the course has a strong relation to the following skills and abilities:

- Ability to critically identify, formulate and handle complex issues
- Ability to create technical solutions
- Ability to design and manage products, processes and systems; Ability to take into account the circumstances and needs
- Ability to verbally and in writing present and discuss problems and solutions in dialogue with different groups.

This is quite similar to the recommendations from the Accreditation Board for Engineering and Technology (ABET) in the United States indicates the importance of design courses:
*"The engineering design component of a curriculum must include at least some of the following features: development of student creativity, use of open-ended problems, development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, and detailed system descriptions. Further, it is essential to include a variety of realistic constraints such as economic factors, safety, reliability, aesthetics, ethics, and social impact."* [19].

## 3 RESEARCH DESIGN

The paper is based on the development of the course and two years of implementation of the course. Data are collected from debriefings with students, course surveys and evaluation at the programme board (student representatives meet with the programme responsible four times per year to evaluate courses). The study was made in the form of action research [20]. The hypotheses for this study were that student motivation can be increased with high but clearly defined course objectives and that active teacher coaching assists in achieving this. The main changes in the course from the previous year were that the course was broken down into several milestones where constructive feedback was given. The overall objectives were made clearer and linked to the overall intended learning outcomes for the education in a more evident way, and that teacher coaching was more emphasized and explained. During the course, the involved teachers made observations and in their role as coaches they could follow the students closely throughout the project. This produced both qualitative and quantitative results for the study.

## 4 RESULTS

The results are based on the design reviews, supervision meetings, and the course survey.

### 4.1 Design reviews and critique

During the course, four different design reviews, (DRs), were carried out. At these DRs the students presented their current project status with emphasis on the specific stage gate. The teaching team responded with in-depth questions on both a general and a detailed level. The students also were given a written feedback on their oral presentation and the PM. The break down into several milestones resulted in a more distinct project process that was easier for the students to understand and follow. The objectives became easier to grasp and fulfil and the continuous feedback and fulfilment of the milestones boosted the students' self-esteem and motivation. The design critique was difficult to handle for some students at first but when clarified it was seen as very useful.

*'It is important that it comes out even if it hurts to accept criticism. Once you've learned from the criticism it feels so much better afterwards!'* (Quote from Course Survey 2012)

It was observed that the students used the feedback to improve their performance for the next DR. The content of the presentation and the quality of the delivery was constantly improved throughout the course.

'*With critique from each design review, you learn what went well and what needs improvement, a good development for both the individual [student] and [other] industrial design engineers.'* (Course Survey 2012)

*'The critique was super; [the project] took into account the economy, design and production thereby creating a realistic project'.* (Course Survey 2013)

The four design reviews also helped the students to distribute the workload.

*'Nice that we had four design reviews – it helped to keep the pace'.* (Course Survey 2013)

Also much more constructive feedback on how to improve the design was provided in a coaching session after the DR.

### 4.2 Observations from coaching

During the individual coach meetings, it was observed that the coaches played an important role when it came time to put things in perspective. To discuss course objectives and to help the students interpret task descriptions made it more comprehensible for the students and kept the workload at an acceptable level. *'...very good with the coaching', 'It was easier to get answers to our questions when we had more personal contact with a specific teacher'.* (Course Survey 2012)

*'It was very rewarding when we got feedback [from the coach] from the DR and assistance at appointments'.* (Course Survey 2012)

*'Lots of work on your own. But the coaching has been good. The teachers also participated in coach meetings outside the course schedule'.* (Course Survey 2013)

*'It has been great to have a private coach. Our group has used extra meetings over scheduled coaching time, which is appreciated'.* (Course Survey 2013)

The students also used these coaching meetings to try ideas, and to get early feedback from the coach. This led to animated discussions between the students and the coach on a very equal level. During coach sessions, the coach also could identify the underlying individual goals for each student and try to make it possible for the student to reach those goals as well in order to increase motivation at an individual level. It was also clear that if the coach showed enthusiasm and dedication, it rubbed off on to the students and they showed a higher level of commitment and responsibility.

### 4.3 Course survey and programme board evaluation

Course evaluation was done both with a survey in the final lecture in the course, where all student participated as well as at the evaluation in the programme board. The survey shows that the students are highly motivated during the course. See Figure 2.

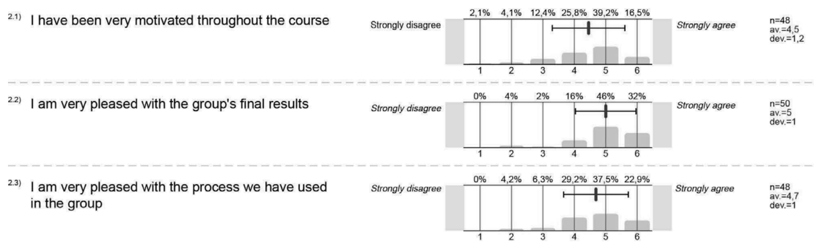


*Figure 2. Extract from course survey*

From the survey we can also see that 85% of the students are satisfied or very satisfied with feedback and support from their coach and that 75% have had regular and frequent contact with their coach during the project. The Design Reviews are considered as positive; 91% say that the feedback during the Design Reviews has improved their result.

## 5 DISCUSSION

One of the limitations in this study is that it has a quite limited dataset; it is based on evolution of one new course over a period of two years. Also the analysis and reflections presented in this paper is the result of being involved in the course as a lecturer and coach. With these limitations in mind some interesting results can be highlighted. The coaching was a critical element for the success of the course. It became obvious during the coaching sessions that the course objectives and deliverables needed further discussion to settle properly within the groups. Because of the fast, pace the students had to deliver immediately, and it was crucial to focus on the right things from the start; there the coaches played an important role. Results from the course survey show that more than 75% (61% in 2012) of the students claim that they have spent more than 100% of the expected 20 hours per week. Because the groups consisted of 4 students, the total available time for each group was 80 hours per week. Looking at the results, including DRs, PMs and final results, the claim to have spent more than 100% seems a bit exaggerated. This might be due to the many deadlines and the feeling among the students of being constantly evaluated. Another reason for this could be inefficient project organization; students are not used to working in projects with time pressure. To properly divide the work between the team members is crucial when working in a complex group project with tight deadlines. This will be pointed out more clearly in future courses. This was also mentioned by one of the students in the survey: *'Clarify for all students that effective group work is of great importance*'. (Course Survey 2013)

## 6 CONCLUSIONS

This paper is focused on increasing student motivation in project courses. The study has been performed in an integrated design course for industrial design engineering students.

The study shows that students are perfectly capable of managing tough and high demands if broken down into manageable milestones.

By using periodic design reviews the students get critique early on, which was much appreciated and was perceived by the students to improve their final result. By completing the individual milestones, the student motivation was boosted throughout the project. Compared to last year, the overall result this year was more elaborated and of better quality. It also shows that it is very important that the students are given proper coaching to be able to manage these demands, where the coaches play an important role to clarify critique, deliverables, and expectations for each stage.

To improve further the course, expectations and demands will be discussed (in an individual meeting between students and coach) in an early stage in the project where a common understanding of expectations will be formulated.

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# A SERIES OF STUDENT DESIGN PROJECTS FOR IMPROVING AND MODERNIZING SAFETY HELMETS

**Johannes DE BOER[1,2], Margot STILMA[1], Karin VAN BEURDEN[1] and Wouter TEEUW[1]**
[1]Research Centre for Design and Technology, Saxion University of Applied Sciences, Enschede, The Netherlands
[2]Human Media Interaction, University of Twente, Enschede, The Netherlands

**ABSTRACT**
The Saxion Research Centre for Design and Technology employs many students during research projects. This paper discusses a series of student design projects on safety helmets in the Safety@Work project. At construction sites workers are required to wear personal protective equipment during their work. However, there is often a lack of intrinsic motivation for wearing them. The series of projects focus on raising intrinsic motivation to wear safety helmets by adding features, and making the safety helmet more comfortable to wear. Co-design principles were used for five consecutive projects. The first projects got a clear view of the problems while wearing safety helmets. Later projects focused on designing prototypes, constructing prototypes, and eventually conducting usability studies with construction site workers. Students are given the opportunity to familiarize themselves with companies, research groups at the university, and test their ideas in the real world. A reflection of the process is described.

*Keywords: Safety helmet, safety by design, co-design, usability studies, industrial environments, sensory influences*

## 1 INTRODUCTION

How can we improve safety at work by using Ambient Intelligence? A safe working environment is not always obvious. A factor influencing safety is human behaviour [1]. People disobey, or are unfamiliar with safety rules. A big issue in the field is that workers dislike wearing personal protective safety equipment (like safety helmets, safety goggles, and boots). Reasons are a personal lack of motivation, uncomfortable designs, and lack of sense of necessity and dangers.

The basic principle behind the Safety@Work project is how to encourage safe behaviour in industrial environments with support of ambient intelligence. Students have the opportunity to use learned knowledge in research-based projects, based on industrial problems. Several consecutive internships and graduation projects eventually work towards a modern, future-proof, and ready-to-market safety helmet. Projects have a small overlay, so students learn from their predecessor. All students present their work to participating companies during consortium meetings. This paper describes the on-going series of these student design projects. The two main directions in the projects were: 1) Finding out into what extent there is a limited intrinsic motivation to wear the safety helmet. 2) How to increase intrinsic motivation of construction site workers to always wear their safety helmet on construction sites.

## 2 PROJECT OUTLINE

The project series developed following an empirical approach. Main goal of the Safety@Work project is to identify different ways to create safe working environments. Therefore the first project of the series started with analysing different possibilities to influence safe behaviour.

The series started with a small study on sensory influence and emotional design [2]. The second study explored theories from marketing psychology [3]. Work by Cialdini [4]–[6] deepened the knowledge on subconscious influencing behaviour and human senses. The study looked into how our different senses are usable to influence safe behaviour [3]. Results showed that both these ways could be constructive. Simultaneously, we learned that constructions sites are confronted with workers who have a limited motivation to wear their safety helmet. Therefore, the findings of both these studies were used in the preparation for a workshop focusing on first steps towards the design of a motivational safety helmet. 15 participants were involved during the workshop in April 2012. All participants studied Industrial Product Design at the Life Science, Engineering & Design department of a Dutch University for Applied Sciences. The two topics chosen for the workshop were the psychology of persuasion, and influencing human senses. The workshop focused on inventing safety solutions based on these topics during several brainstorms.

Regarding the first topics, Cialdini [4]–[6] studied the psychology of persuasion. He discussed six principles of persuasion to influence behaviour in his research. The principles work as shortcuts for decision making in our sub consciousness. According to Cialdini, we created these shortcuts because when we would have to spend time and energy to consciously consider every decision, we would quickly become paralyzed. These principles, preliminary studies for marketing purposed, a starting point for the workshop. During the workshop we explored the possibilities on how to use these principles for safety purposes.

Analysing the design concepts, we see that some concepts improve safety directly. These concepts added safety-improving elements to the helmet: For example the added safety glasses to the helmet. Other design concepts focused on improving safety indirectly, by increasing the motivation and pleasure to wear the helmet. For example, one concept introduced fashionable safety glasses. Focusing on fashion might motivate the workers to wear their glasses more often, resulting in a safer working environment. Other concepts focused on rewarding the wearer in different way, or in improving the comfort by regulating heat

The second topic covered in the workshop was the influence of human senses. In an explorative study, Bondrager [2] discussed several ways to influence behaviour by our senses. Participants of the brainstorm were challenged to use the ideas of sensory influence in their concepts. In some concepts, improving safety was taken to a higher level. In the case of the lemon smell, the helmet was used as a mean to get a cleaner construction site as lemon smell induces cleaning behaviour. Table 1 shows how the different concepts mentioned during the workshop contribute to safe behaviour, based on the categories comfort, safety, and reward.

*Table 1. Summary of concepts invented during workshop* [7]

| | Comfort | Safety | | Reward |
|---|---|---|---|---|
| | | Indirect | Direct | |
| Music | X | | | |
| Lemon smell | | X | | |
| Wearer of the month | | | | X |
| Design glasses | X | | | |
| Integrated safety glasses | | | X | |
| BAM girls | | | | X |
| Hearing protection | | | X | |
| Personalisation | X | | | |

The workshop led to a further focus on improving safety and improving motivation to increase safety indirectly.

### 2.1 Motivation for safe behaviour

The two studies mentioned earlier [2], [3], in combination with the workshop, were input for a project that studied the influence of primary benefits on the motivation for safe behaviour [8]. From the wide range of design concepts in the workshop, Wanders chose to focus his internship on direct safety solutions. To gain more in-depth insight into safety issues and safe behaviour, an overview of accident causes was used. This was the basis for new concept design study. The top 10 categories with the most incidents are mentioned in Table 2, based on a report from the Ministry of Social Affairs and Employment [9].

*Table 2. Incident rates in the Netherlands 1998-2004*

| Type of incidents | Per year, in numbers | Percentage |
|---|---|---|
| Fall from heights | 98 | 21% |
| Fall from ladder | 73 | 16% |
| Fall from scaffolding | 60 | 13% |
| Contact with falling objects (various) | 45 | 10% |
| Contact with moving parts of a machine | 36 | 8% |
| Contact falling object from cranes | 16 | 3% |
| Contact with flying objects | 13 | 3% |
| Contact with wielding objects / hanging loads | 13 | 3% |
| Contact with electricity | 12 | 3% |
| Collision with vehicle | 10 | 2% |

Based on the earlier studies, literature, interviews, and a brainstorm with design students, seven concepts were developed. These concepts benefit to safety by increasing the motivation to wear a helmet. The beneficial part in this case was adding functionalities that construction site workers would appreciate and benefit from in a helmet. The seven concepts integrated in safety helmets are briefly described in Figure 1. Four of the concepts added a warning system in the helmet for potential dangers. The other three concepts added work time registration, integrated two-way radio, and machine lock when the helmet was not worn.

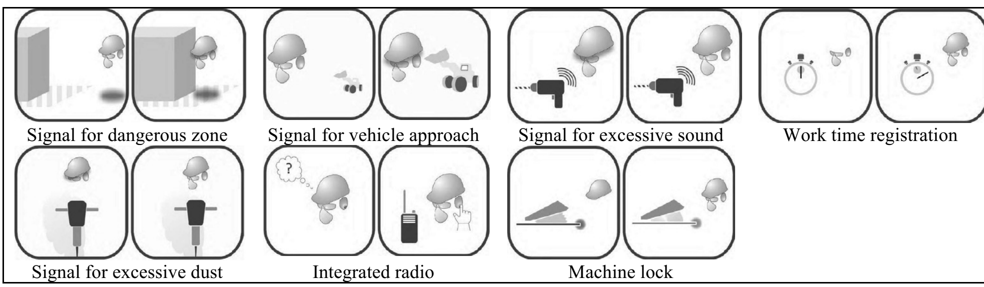


*Figure 1. Concepts for added functionalities in safety helmets. (Wanders* [8]*)*

In order to reflect these designs with construction site workers, three prototypes (see Figure 2) were built. In these prototypes all concepts were integrated. The functionalities in the prototypes were tested with a wizard of Oz method. 8 construction site workers participated in interviews during a workshop. They took part in a demo wearing the prototypes and reacted to work simulations. Interviews were planned to discuss the prototypes, and were conducted by the succeeding grad student.

Light signal for excessive amount of dust & dust mask | Signal for excessive sound & integrated ear protection | Machine lock (deactivated when wearing helmet), dangerous zone, and approaching vehicle detection

*Figure 2. Prototypes with added functionalities*

## 2.2 Usability study for a functional modal

Starting point for the next student project was a usability study to test the concepts of Wanders [8]. This study was conducted in February 2013, with ten construction site workers. These workers got an extra break of 30 minutes during their work to participate in the study. The prototypes were used for a PowerPoint-based simulation with 10 participants. Participants of the study got several assignments, related to workplace safety. The assignments were alternated with pictures of the prototypes. Afterwards a questionnaire was handed out to the participants.

The results of this conducted usability study by Lemmens [10] showed that not all problems found by Wanders were equally relevant. Also, some issues were discovered that were not included in the earlier studies. E.g. Construction site workers tend to bump their heads more often when wearing safety helmets, because of a lack of sense. Most workers indicated that they wore their helmets because it increased their safety, and because it was expected of them. However, part of the workers did not show any intrinsic motivation for wearing the helmet. For example, 1) a helmet was demonstratively thrown onto the ground; 2) a helmet was broken and still not replaced for a new safe one; 3) sun vision protection was sown off, to create better sight. Construction site workers reacted positively on the concept of an integrated smart system. Lighting signals or warning sounds were seen as unusable as they could hardly be seen in daylight or heard on site. Based on the findings during the interviews a new integrated concept was designed (see Figure 3).

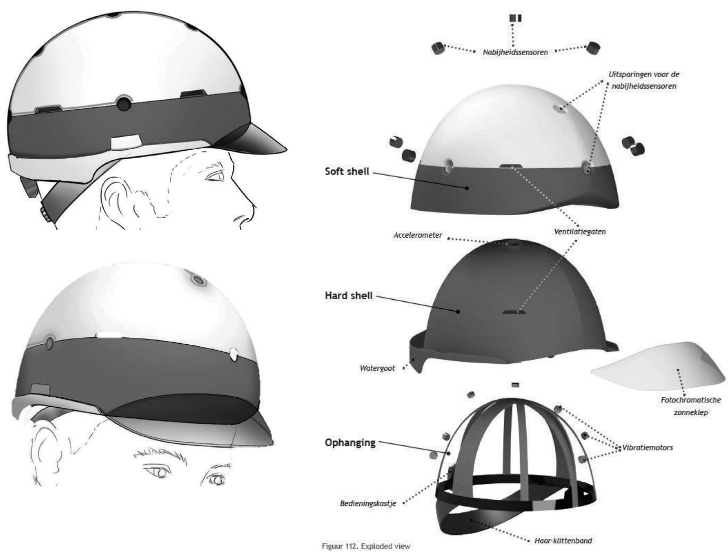


*Figure 3. Integrated conceptual safety helmet*

Lemmens [10] elaborated on the focus of Wanders [8] by stating that feeling safe results in being and doing more safe. More information from literature was gathered to get to know more about safety and motivation. Motivation can be both intrinsic and extrinsic, safety both directly and indirectly, but also has a design component. Designs with a safe appearance might induce a higher motivation. This does not mean it the design is safer as is, but it may add to a safer feeling. For further clarification see Figure 4, based on [10], [11].

Lemmens' concept focused on multiple aspects of the safety helmet mentioned in the earlier studies. In the concept the comfort factor played a huge role. A photo chromatic sunshade was build-in, and in addition a Velcro (inspired) neck strap prevented the helmet from sliding of the head. The second aspect was an early warning system for nearby objects. This warning system used ultrasonic sensors (distance sensing) and vibration motors (like in smartphones) to alert the wearer of nearby objects. In addition, the outside of the helmet is made of soft materials. The soft shell gives the helmet an additional barrier that prevents damage to the hard shell when the wearer bumps his head [12].

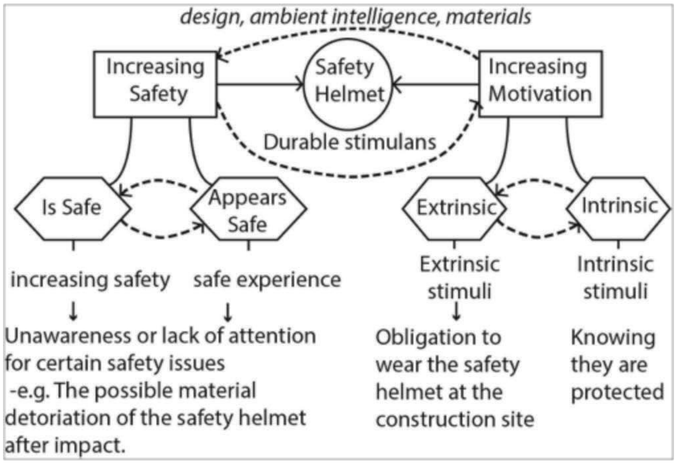


*Figure 4. Aspects of motivation and increased safety for safety helmets* [11]

### 2.3 Integrated prototype and usability study

With the design of the integrated conceptual safety helmet of Lemmens [10] a new project was started. Goal of the project was to build a prototype and test it with construction site workers. The project started with a feedback session with construction site workers. The same setup as the previous usability studies was used. A total of 8 construction site workers participated. The project studied specifically in which ways the new design could contribute to the personal motivation of construction site workers to wear the helmet [13]. Two prototypes were made: 1) A functional prototype that encompassed all functionalities from the design, and 2) A sight model that had the look and feel of the design. The design is based on motivational theories such as by Deci & Ryan [14]. Integrating both prototypes into one was not possible because of time and cost constrains.

As a next step, Beldman [13] developed a model to encourage long lasting motivation. Starting point were three kinds of stimuli: 1) internal stimuli (competence, autonomy, and connectedness), 2) autonomous stimuli (values and aspirations), and 3) external stimuli (appreciation). Based on the prototypes and theories, a usability study was conducted. After evaluation of the usability study with construction site workers [13], it appeared that the prototype was appreciated, but not in its current form. Most comments on the design regarded comfort related aspects, which relate to current safety helmets as well (such as heat generation). Other comments regarded the (perceived) heavy weight of the safety helmet and the (un) comfortable fitting of the helmet on the head. Moreover, from a technical point of view, embedding sensors through the shell is possibly not accepted due to strength qualifications. However, a helmet with high comfort and added functionalities can contribute to the intrinsic motivation for wearing the helmet.

Based on these results, first steps were taken to develop a new helmet from a constructive point of view. However, these ideas are still in a preliminary phase.

## 3 THE PROCESS / REFLECTION

The Safety@Work project enables students to connect education and applied sciences, in order to improve their skills. Researchers coordinating the projects guide the student through several design steps, and force quality control for the series of projects.

For students, it gives them the opportunity to familiarize themselves with companies, applied research, and test their ideas in the real world. A main advantage of using a series projects is the ability to shift according to the developments in the parent project. The approach takes advantage of the availability of students with diverse skillsets, and the embedment of research in their curriculum. A main advantage for the students is that they learn to elaborate on recent, earlier work. Knowing that their work is used immediately for the next phase of the project ensures the quality of their research. For the project it ensures a high probability of succession for the next phase. However the essence of the series is an avoidance of one specific focus throughout all the projects. While the project evolves, the series changes accordingly. Different perspectives of the students can be used in each phase. A drawback of the method used is that research from one student project is not always used in later phases. For example: The first studies looked into the work of Cialdini [4], [6], while later studies completely neglected that knowledge and focused on motivational theories [14].

For researchers, student projects enable them to get more in-depth work done parallel to their own research. The multidisciplinary backgrounds of students add to the variety in outcomes of the project. Beforehand, the end goal of the series was determined as 'the design of a new, modern safety helmet'. The route towards that goal, and the precise final product were not determined. The project was not divided in subprojects focussing on a phase of the production and design process. At the end of each student project result are evaluated, and decision were made for the focus of the next student project. The research line throughout the different projects had an empirical character. Reactions from construction site workers and management staff of construction sites underlie the need for improved and modernised safety helmets.

## 4 FURTHER WORK

A final and ready-to-market design is still a few steps away. However, a continuation of consecutive student research projects will work towards that goal. During the remainder of the Safety@Work project, there will be a focus on two topics. The first topic is the integration of the sensor system in the helmet with a separately developed sensor shirt. The shirt uses a platform of wireless sensors. The sensors in the helmet could be connected to the same platform to share collected data.

The second topic for further developments is on the used materials in the new helmet design. From the area of smart textiles a study will be conducted that focuses on the used textiles, and the protectiveness of different types of rubber.

For the future we expect a further development of projects in this field, especially in combination with Living Technology program currently developed at our university. New opportunities arise in this because of the program's interdisciplinary approach for research projects.

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# INSECTS AU GRATIN - AN INVESTIGATION INTO THE EXPERIENCES OF DEVELOPING A 3D PRINTER THAT USES INSECT PROTEIN BASED FLOUR AS A BUILDING MEDIUM FOR THE PRODUCTION OF SUSTAINABLE FOOD

**Susana SOARES and Andrew FORKES**
London South Bank University, United Kingdom

**ABSTRACT**
*Insects Au Gratin* focuses on the future of food and explores the nutritive and environmental aspects of entomophagy (eating insects), combined with 3D food printing technologies.
The project has been investigating the possibility of using 3D dimensionally extruded insect paste filament as a method of creating foodstuffs, although the notion of printing food is not a new development, the innovation of using insect paste as a build medium is highly novel, this coupled with farming insects could create a sustainable source of food for an increasing global population. Why insects? Although entomophagy is alien to the western society, people in non-western territories eat insects as part of a regular diet. Insects are very efficient at converting vegetation into edible protein, full of vitamins and minerals: four crickets provide as much calcium as a glass of milk, and dung beetles, by weight, contain more iron than beef. Farming insects generates one-tenth of the methane produced by farming traditional meat sources per kg and it uses comparatively little water.
The focus of the paper is based upon the development work for two public engagement events as part of Pestival held at the Wellcome Collection in London and the World Food Festival in Rotterdam. The events aimed to explore and debate the potential of entomophagy as a sustainable food source as well as combining with new food production technologies and how those could affect human perception of food and technology.

*Keywords: Future food, 3D printing technologies, entomophagy, insect paste, open source*

## 1 INTRODUCTION

The project activity represents an unique partnership among the subjects of food technology, entomology, engineering, programming and product design. The objective is to exploit the aesthetics of food and the media attention by using new 3D food printing technologies as well as using the potential of insects as alternative source of protein and to incorporate these raw materials into feed or directly into food products. Issues related to food aesthetics, novel technologies, nutrition and raw material functionality are being investigated. The project aims to stimulate research into new food technologies through design thinking and engineering, raising the profile of new protein sources and developing innovative food products using new technologies. The activities associated with the project include:

- Accessing a consistent supply of insects. Suitable sources include mealworms, crickets and silkworm pupae and the potential to incorporate local species are being investigated.
- Micro scale insect farming and experiments with feeding the insects in order to develop a naturally 'flavoured' insect protein have been explored.
- Insects are harvested, dried and milled into a functional food raw material suitable for 3D printing.
- The raw material is being analysed for its nutritional composition.
- The raw material has been successfully combined with other food products, which can be extruded into various shapes demonstrating the potential for 3D food products encompassing insect protein.

These experiments were exhibited at Edible - Science Gallery Dublin, Ireland (Figure1); MART, Italy, St. Etienne Biennial, France; Who's the Pest? by Pestival at Wellcome Collection, United Kingdom (Figure 2); and Future Food House, World Food Festival, The Netherlands (Figure 3). The project has encouraged the development of students work amongst the areas of food technology and engineering product design generating transferable skills and cross pollination of ideas.



*Figure 1. Insects Au Gratin at Edible, Science Gallery; Figure 2. Insects Au Gratin installation at Wellcome Collection; Figure 3: Insects Au Gratin exhibition for Future Food House, World Food Festival*

## 2 BACKGROUND

The *Insects Au Gratin* was conceived in 2011 as part of *Edible* [1] exhibition at Science Gallery in Dublin. The project starting point was based upon two major premises:
1. In 2008 the Food and Agriculture Organization of the United Nations (FAO) made an appeal to the world population to eat less meat. FAO estimated that direct emissions from meat production accounted for about 18% of the world's total greenhouse gas emissions and strongly supported research aimed at reducing methane emissions from livestock farming [2]. According to Gimenez 'in addition to the global economic crisis and high prices for food, the effects of fluctuating weather patterns as a result of climate change, extremely low grain reserves, high oil prices, the increase in biofuel production, and the *meatification* of the global diet have contributed to the increase in the number of hungry in recent years' [3].
2. The University of Wageningen [4] research on entomophagy investigates the potential of insects as a novel protein source. The research showed the farming of insect meat has a better feed conversion efficiency, being more sustainable than the production of conventional meat. The intent is not a replacement of traditional meat based foodstuffs but as a supplement to a balanced diet.

### 2.1 Edible insects future food

More recently, in May 2013, FAO has published a report that concludes into encouraging people to consume edible insects as a driver to promote behavioural changes towards more sustainable ways of ingesting protein. Insects have a high nutritional value are rich in protein and good fats and high in calcium, iron and zinc; they emit less greenhouse gases compared with traditional livestock [5]; insect rearing does not require a vast amount of land use; since they are cold blooded crickets, for example, need 12 times less feed than cattle, four times less feed than sheep, and half as much feed as pigs and broiler chickens for the same amount of protein; insect harvesting/rearing is considerably low-tech in comparison to meat, naturally organic due to lack of antibiotics and pesticides used in their welfare[6].

### 2.2 The yuck factor

It is estimated that insects form part of the diet for about 2 billion people around the world, with more than 1200 edible species used as human food. Entomophagy is strongly influenced by culture and in most Western societies eating insects is associated with a 'yuck' factor. 'Edible insects have always been a part of human diets, but in some societies there is a degree of distaste for their consumption' [7]. The *westernisation* of eastern food cultures will promote even more uncertainty for future food sustainability. *Insects Au Gratin* aims to tackle that 'distaste' by exploring the aesthetics of food offered by 3D food printing technologies, looking at new ways of designing and or cooking insects. Moreover the average person already consumes about a 0.45kg of insects per year, mostly inadvertently mixed into other foods during conventional production processes.

## 2.3 The impact of aesthetics of food in food acceptance

The impact of aesthetics on choice is robust and well documented for physical product choices. At least two different studies showed that consumer response to the sensory properties of food (particularly appearance, flavour, aroma, taste and texture) is an important factor in determining the success of new products [8]. According to the *Art on a plate* authors on the impact of a food product physical appearance "It was concluded that expectations of liking for a food generated by appearance influenced final evaluation of the product during consumption." [9].

Food is a sensory as well as a social experience and taste is more than a gustatory perception, it is also a metaphor for social constructs of appreciation. Therefore, the aesthetics of food products containing insects are an innate aspect to tackle concerning entomophagy acceptance in Western cultures.

# 3 THE PROCESS OVERVIEW

The *Insects Au Gratin* project looks at the various aspects of the whole insect food production process. From harvesting insects, to grind various species of insects into a powder, to mix that powder with another food product that functions as a carrier, to 3D food printing to their consumption (Figure 4).

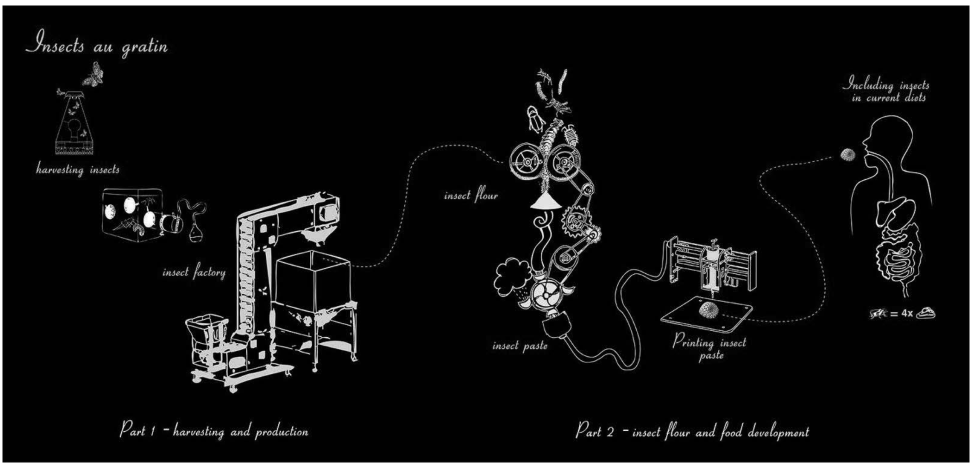


*Figure 4. Insects Au Gratin illustration of process*

## 3.1 Insect flour

Edible dried insects are ground into powder. The resulting insect flour is mixed for the prototyping process with other food products such as icing butter, chocolate, cream cheese and spices such as ginger, cinnamon, dried chillies to form the right consistency to go through the nozzle.

## 3.2 Food design using polygon CAD sofware

The initial proposed designs used common professional NURBS/polygon based CAD software that were exported to a STL file format to be printed (Figure7). The shapes were inspired by insects' natural forms and movements, such as their delicate wing patterns, microscopic images of insect eggs or the bees 'waggle dance' in an attempt to extract the inner beauty of such elements (Figure 5 and 6). The aesthetic decisions were also aligned to public display in order to catch audience attention and spark the debate around entomophagy, food acceptance. Their complexity and intricate design detaches it from recognisable food shapes and resembles jewellery as a way of communicating future problems with food prices. Food products might become a luxury if predictions about food scarcity and consequent rise in prices became reality.

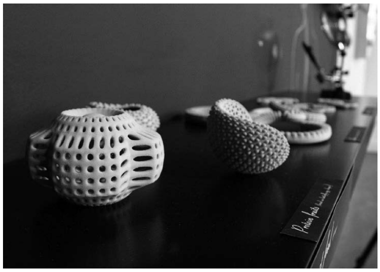
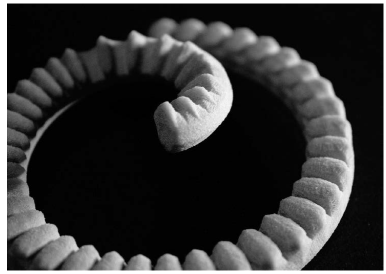

*Figure 5. Aesthetics inspired by insects natural forms and patterns; Figure 6. Texture relates to caterpillar's shapes*

### 3.3 Iterative development

After being exported to a printable format the files need to be sliced into printable layers, re coded based on the delivery performance of the printer head and re arranged to be able to be printed using a paste base or food product. A series of open source stereolithography (stl) slicing and conversion software were used to achieve the file coding, this was then modified iteratively to print a reasonable food prototype (Figure 8). It takes an average of 4 minutes to print a file that contains 10-12ml of insect flour mixed with spices (Figure 9) and a binder (icing sugar fondant). The timescales for development on this project were restricted to various requests to attend events with the printer prompted reassessment of the project status. Existing technology was 'hacked' for the project means rather than a representation of a 'slick' virtual model, this allowed empirical advances and learning about the relationship between paste viscosity, print coding, binder material, ambient / material temperature and importantly the relationship with the final taste of the printed product.

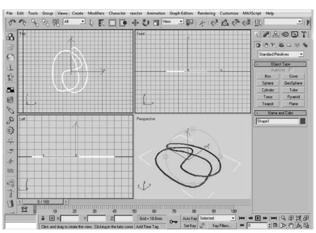
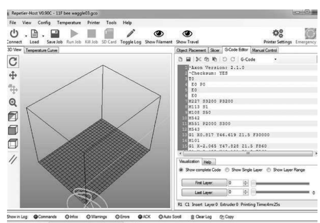
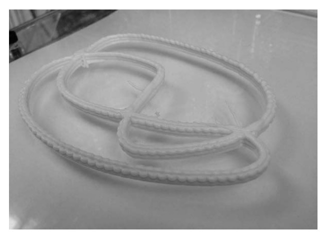

*Figure 7. Polygon based CAD software is used to create the initial printable file; Figure 8. Conversion of file to gcode; Figure 9. 3D food printed insect paste using icing sugar as a binder*

### 3.4 Why 3D printing?

3D food printing technologies: facilitates the process of modifying insects initial appearance which is seen as a factor that deters people from eating them, enables the development of new cooking methods and experiences, through a click. By digitising food design it increases the potential for the development of a new aesthetic related to food and combine what can be a potential sustainable process with a sustainable food product.

## 4 CREATIVE COLLABORATION METHODS

In order to develop the project we have formed cross faculty and external partnerships as well as building upon open sourced working methods. The team's food scientist has developed a range of insect flour material that is combined with spices and a fondant to produce a material that can be printed. There was significant iteration in both the codification of the part files and the grade of milled protein, the results can be shaped into various designs that are aesthetically manipulated through the aforementioned software.

### 4.1 Building on the work of others, Open source donor prototypes and Codification

A vital aspect of the realisation of this project was capitalising on the time compression afforded by the use and modification of donor components from open source websites such as "thingiverse"[10], this allowed a focus on the critical aspects of coding for delivery, rapid iteration of design ideas and time to explore and test results relating to variations in the viscosity of the paste from changing elements of the drive coding in the second phase of the research.

Radical uses of 3D printing technology may enable us to overcome the traditional aesthetic issues of entomophagy by allowing the users to manipulate the food digitally as a future pastime and challenge people's perceptions of eating insects. The use of insect protein as a 'printable' material opens up a range of new applications and questions existing thinking about sustainability, raw materials, nutrition, food culture and culinary explorations.

## 5 PUBLIC ENGAGEMENT

A key indicator of interest in the eating of insects was evident at public engagement events such as the *Insects Au Gratin* workshop at the Wellcome Collection as part of Who's the Pest? by Pestival (Figure 10). Members of the public reserved a place for the workshop sessions run by the *Insects Au Gratin* team, they were taken through the key stages of the project and voiced their interest and opinions culminating with a virtual food creation session where modelling clay was used to create insect *hors d'oeuvres* based on their personal reflections about the concept. It was intended to create real time CAD models of a chosen design but time constraints dictated that this was not achievable. The paper plates that the models were served on were also used to garner insight and feedback about the project (Figure 11).


*Figure 10. Insects Au Gratin workshop at Wellcome Collection; Figure 11. Example of paper plate with food model and feedback*

## 6 OPPORTUNITIES

It has already been demonstrated that the activity has benefited from an inter-disciplinary approach and is capable of attracting positive media publicity and funding. Proof-of-concept work was presented at the Future Food House, in Rotterdam, Sep-Oct 2013. The exhibit included a 3D food printing demonstration for creating edible items from insect flour. The project attracted significant attention in the national and international media and was cited in a review article in the prestigious science journal Nature, on the website of Wired and New Scientist magazine. The project featured in Who's the Pest? BBC Radio 4 and made BBC World News in April 2013. As an expansion of this project it is felt that it would needed to revisit the original concept and consider notions of the quantified self, possible uses for food aid and the Internet of things.

## 7 EDUCATIONAL BENEFITS

The project has benefited the student experience: two undergraduate projects in Food Science developed high nutritional cereal bars and bread that contained insect flour. Design and Engineering students have been assembling 3D printers as a project based learning activity with the aim to enhance the technology by experimenting with varied delivery systems. This would generate transferable skills that can be of use in their major undergraduate / postgraduate projects by allowing the students to observe and follow the project progress.

Currently there are plans to include a range of student disciplines to the project under direction from the authors, the inclusion of students into the project would be an extra curricular project as it is perceived that a whole cohort contributing to the project would outweigh the benefit.

As an element of the design students education it is felt that the project is a good example of empowerment through product design for behaviour change [11] this can be employed as part of the educational provision where design students can evidence their learning through a broad range of narratives, including product re-design, new product development and arguably invention.

## 8 CONCLUSION

The success of this activity will rely heavily on strengthening links with external organisations, developing new networks and seeking new partners. As with all form of radical uses of technology transfer the aim is to generate a momentum so the process moves from novelty through niche and becomes the norm. The authors are currently investigating various avenues for the research project to become a reality, part of which is to look into the possibility of setting up insect farming facilities, distribution channels and development of a domestic printer that can deliver the product defined by the user.

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# THE CAPABILITY APPROACH: THEORETICAL DISCUSSION IN LIGHT OF A DESIGN PROJECT

**Julie GRANDE and Brita Fladvad NIELSEN**
Department of Product Design, NTNU

**ABSTRACT**
Technological solutions can play a vital part in promoting development. This article will discuss the potential of using the capability approach in the practical design work, based on field study of energy solutions for refugees in eastern Ethiopia.
Extensive literature discusses capability approach in disciplines ranging from philosophy to economics. In technological studies research is conducted in a totally different manner. This article is a contribution to the understanding of how the capability approach can be applied in a practically in design.

*Keywords: Capability Approach, Design for development, Social Design, Design Methodology*

## 1 INTRODUCTION
The starting point of this article was Ilse Oosterlaken's article Design for Development: A Capability Approach, which was published in the journal Design Issues in the autumn of 2009. In this article Oosterlaken points to a lack of focus on development and global justice within the field of design. She argues that there are well-developed theories around designing for a market, but little on the field of social design. For this purpose she suggests the capability approach as an alternative theoretical framework.
The economist and philosopher Amartya Sen first introduced the capability approach in 1985. It is a theoretical framework for assessing well-being without imposing one's own notions about what a good life should contain. Sen's motivation to develop this approach was dissatisfaction with the existing methods in this area (Robeyns 2011). Applications of the approach have so far ranged from assessing small-scale development projects to gender inequalities (Robeyns 2005). There has however been considerable discussion around the applicability. Oosterlaken sees technological development and industrial design as an expansion of human capabilities, and thinks that the details in design should be considered in this perspective (Oosterlaken 2009).

### 1.1 Research gap and approach
To the authors knowledge there is no literature on the practical applicability of the capability approach in a design context. In this article a step will be taken in that direction. The focus will be on identified challenges regarding the applicability of the approach. Through revisiting a previously conducted student project the issues defined in literature will be discussed in a practical design context.
This article starts with a presentation of the capability approach to clarify the motivation and idea behind it. The theoretical discussions around the approach will then be presented with the identified challenges of its applicability. These challenges will then be discussed in light of the aforementioned student project.

### 1.2 Introduction to student project
The student project in question is based on a case study of an ethanol cook stove provided for refugees in the camp Kebribeyah in eastern Ethiopia. The camp was set up to receive refugees from Somalia at the onset of the civil war in 1991. Most of the refugees have lived there since.
Semi-structural interviews with refugee women were central in the field study, supported by observation when cooking, general observation in the camp, semi-structural interviews with stakeholders involved and a visit at touchpoints between the refugees and the service of household energy provided for them.

During the first trip to the refugee camps it became evident that the main challenge concerning the stove was the provision of ethanol. This led the refugees to use the available but expensive alternatives firewood and coal. In the eastern part of Ethiopia the use of firewood has been banned, because the area has been deforested extensively the last years. Without the ethanol the refugees are forced to break this law to be able to cook the rice they are provided.

## 2 THEORETICAL BACKGROUND

The capability approach is a framework pioneered and advocated primarily by Amartya Sen and Martha Nussbaum. It arose from the need to measure progress in development, and the dissatisfaction with existing methods in the field of economy (Robeyns 2011).

Many existing methods in economy measures progress by looking at hard facts like the income level in a country or the amount of resources accessible to its inhabitants. The GDP is a number often used to compare countries' levels of development. This however says nothing about how the resources are distributed within the population. Discrimination on the basis of gender, ethnicity or disabilities is hence not accounted for. One can for instance see that South Africa had a quite high GDP during the apartheid years (Nussbaum 2011).

Other approaches like the Gini coefficient (Yitzhaki 1979) are based on economic growth while also accounting for the distribution of resources. However, Amartya Sen and Jean Dreze has found evidence that economic growth does not directly lead to better health care or education systems, elements that must be considered central in a development context (Sen and Dréze 2002).

The goal of developmental work may be seen as giving everyone a good life. So why not measure happiness? This is the aim of the utility approach. It is based on quantifying people's satisfaction with different aspects of their lives (Nussbaum 1997). Happiness is however a relative and abstract quality that is hard to convey in words, much less numbers. One could also say that since the ultimate goal in the utility approach is a state of happiness, it is the conditions at the current that is important in the assessment. That people have a say in these conditions is hence not valued. In the extreme one can say that with a government that make people happy, democracy is no longer important (Nussbaum 2011).

The Human Rights approaches come closer to the philosophy behind the capability approach. They aim to secure the freedoms that are central for human beings (Alexander 2004). The Universal Declaration of Human Rights is a good example of such an approach in practice. There is however a central weakness in these approaches, pointed out by Nussbaum. In her opinion the term "right" can be understood in many different ways, meaning that this approach lacks clarity.

Through this reasoning we have come to the centre of the capability approach. What Sen and Nussbaum suggest as a solution is looking at "what people are effectively able to do and be" (Alkire 2005). There are three main terms discussed in this context; functionings, capabilities and agencies. The functionings of a human being describes what the person does, has and is, in other words the realized aspects of his or her life. The capabilities on the other hand are the functionings that are effectively realizable for this human being, meaning the opportunities that in reality exist. This distinction is made to avoid cultural bias, because there is no need to define good and bad choices if one focuses on capabilities. The term agency is closely related to that of capability. Capability can be seen as the freedom to enjoy various functionings (Alkire and Deneulin 2009) while agency is a person's ability to pursue and realize those functionings. Agency hence accounts for the individual differences in the choices people make.

Up to this point in the discussion Sen and Nussbaum agree. The capability approach is still a very vague framework, which is also the background for their debate. Sen advocates keeping the approach at this level, because its strength lies in the fact that it is not biased. Any evaluations of which capabilities that are important to a human being would be to ascribe the target group values they might not share. Relevant capabilities are subject to both purpose and context and should in his opinion not be decided by theorists (Sen 2004). Nussbaum argues that by keeping the approach this vague, one cannot exploit its full potential. In her opinion the approach in this form can only be applied comparatively, comparing regions or nations on a certain aspect, but that the approach also has a potential for normative use (Nussbaum 2011).

A normative use of the approach means that it inflicts a judgement between right and wrong. Nussbaum sees the potential for evaluating social justice in a country without comparisons, and hence the use in processes like constitution making (Ibid.). She goes on to define a list of ten basic capabilities that she finds universal on philosophical grounds. The list is developed with a basis in what human dignity depends on, and consists in her opinion of the most basic elements. The capabilities are mutually supportive, but cannot replace each other.

# 3 PRACTICAL APPLICATION

## 3.1 Defined challenges

The capability approach has been discussed widely, but since the birth of the capability approach in 1985 the empirical evidence is still very limited (Robeyns, 2006). Through a review of studies applying this approach Robeyns have found that nearly all applications have been quantitative. All the quantitative applications have been built on existing surveys, and all are mainly based on functionings. This gives little background for discussing the possible impact of using this approach and the discussion is primarily on a theoretical level.

On one hand the capability approach has received critique for not bringing anything new to the table. Some say that the approach is too closely related to existing methods and frameworks in the social sciences. An answer to this is that the approach is still quite revolutionary within the field of economics, where it has its origin. In design, like in the social sciences, focusing on the human being is not new.

The starting point of this article was Ilse Oosterlaken's article Design for Development: A Capability Approach, which was published in the journal Design Issues in the autumn of 2009. In this article Oosterlaken points to a lack of focus on development and global justice within the field of design. She argues that there are well-developed theories around designing for a market, but little on the field of social design. For this purpose she suggests the capability approach as an alternative theoretical framework.

Ingrid Robeyns has worked on operationalizing the approach, and accuses the approach of being "radically underspecified" (Robeyns 2006). She points out three problematic areas where specification is needed for the capability approach to be useful in practice.

## 3.2 Challenges in light of design project

One of the main arguments Oosterlaken gives for applying this approach in the field of design is that the goal of technological development is to expand our capabilities as humans (2009). That it is relevant does not however prove that the capability approach is valuable for the design process. This requires that it has a potential to expand on the existing methodology.

The problematic areas defined by Robeyns will now be used to evaluate the use of the capability approach in the previously mentioned case study/design project.

### *3.2.1 Deciding between functionings and capabilities*

Sen and Nussbaum have in their work paid greatest heed to capabilities. By looking at the possibilities people actually have, they see great potential for evaluating the quality of life. For other purposes it might be more relevant to look at functionings, what a person is, has and does, depending on the aim of the research. The latter option is more applicable in practice, simply because it is easier to observe what people do than to find out what they have the possibility to choose. However the main innovation with this approach lies in the capability dimension, which is what separates it from the existing approaches.

As is true for different types of research, design projects will also have different aims or motivations. Functionings will naturally be interesting in a project with focus on functionality, first introduced through the field of ergonomics following the invention of the fin the 1960s (Øritsland and Vavik 2008). Capabilities, being tied to the possibilities that are effectively available, contain a social dimension especially suitable in social design.

Though it was not discussed in the design team beforehand, there was a clear social motivation behind the student project. To look at capabilities would hence be a natural choice. However, studying the interview guides and the terminal findings from the field study, the definition of the term capability is not so clear anymore. How do you define which options that are effectively available to someone? The interview guides from the field study does not focus mainly on which choices that were available to the refugees, but also on what they chose and what they wanted to choose. The need for such a broad spectrum can be explained by the relativity of the term capability.

Naturally, if a choice is available to someone or not theoretically is not the same as it being *effectively available* as the original definition states. Though a refugee can deliver a broken stove to the technician, this might not be effectively possible. The family has to do without the stove in the meantime, the stove has to be delivered at a certain time and the refugees need to receive the information as to how this system works. Suddenly if a choice is effectively available is very relative. How long can the reparation take for it to be an actual option to the refugees?

#### *3.2.2 The selection of relevant capabilities*

Nussbaum and Sen agree upon that the capability approach needs to be adapted to the context, but they disagree on the level of this adaptation. Even with the list Nussbaum provides, Robeyns sees the need for further specification for the approach to be applicable in practice (Ibid.). There have been extensive discussions around how this should be done, ranging from theoretical evaluations to survey based statistical methods.

In a practical design project there is a greater liberty of defining what kind of information one is looking for, compared to academic research. The selection of relevant capabilities is still very dependent on the context, but the requirements for scientific accuracy in design project is not as strict as in academic research. The designer uses a combination of creativity and analysis when planning a design process, and is a possible approach here as well.

Designers should of course strive towards scientific perfection in their methods, but in practice this is utopic. There will always be some practical constraints that lead to trade-offs. This can be illustrated with the case study from Ethiopia. Before doing interviews in the refugee camps, the phrasing of the interview guide was thoroughly planned to not be suggestive and to provide the relevant answers. In the interview setting the planned guide could not be followed. Phrasings had to be simplified to ensure that the questions were understood, and leading questions had to be used for confirmation of a common understanding of the information that was given. To not be suggestive but at the same time be very clear and basic in your communication is not easy. With a communication chain going from English to Amharic to Somali to Amharic to English again, scientific perfection cannot possibly be achievable. The challenges discussed in theory hence are distant from this kind of project.

Choosing relevant capabilities for a project can be a challenge, but the experience from this project is that it is beneficial for a team to take that discussion to ensure they are working towards the same aims. However, here the discussion happened after the field study was conducted after having processed the information retrieved. As might hold for true for many design projects, the selection of relevant capabilities ultimately came from the users themselves.

#### *3.2.3 The weighting of different capabilities*

The importance of each capability is not necessarily equal. To use this approach in quantitative research one is dependent on quantifying the relative weights of capabilities. Three methods for doing this have been presented in literature (Robeyns 2006). The first method is that the researcher chooses the relevant capabilities based on theory or contextual circumstances, a second applied method bases the weighting on statistical methods, derived from surveys or similar, and a third is based on letting the relevant group of people decide the weights. This could for instance involve participatory methods. Sabina Alkire finds the necessary evaluation of dimensions an advantage, because it forces a thorough evaluation of the trade-offs that are being done (2002).

When weighting different capabilities the challenges regarding bias and scientific accuracy are also central, which relates to the experiences described in the last section. Weighting does not necessarily mean to assign each capability a value but to do some kind of comparative evaluation of their importance. In this field study such an evaluation could possibly have structured the process of choosing a goal for the design project, but the aim that was ultimately chosen would most likely have be more or less the same.

## 4 CONCLUDING REMARKS

Through looking at the theoretical discussion around the capability approach in light of a practical design project it seems likely that the challenges discussed are of less importance if the framework was applied in a practical project. At the same time other issues arise that need to be considered, since real life is not as black and white as the theories behind it.

The terminology and problems discussed is easily connected to a practical design project, which implies an absolute relevance of the capability approach to the field of design. Whether it has a value to add is however not considered in this discussion. This requires that it can expand on the existing methodology, which is an interesting topic for further research.

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# REPRESENTATION AND EVALUATION OF PRODUCT DESIGN IN RESEARCH ASSESSMENT: A CASE STUDY OF THE UK REF 2014

**Carmel MAHER[1], Mark HADFIELD[2], Maggie HUTCHINGS[3] and Adam DE EYTO[4]**
[1]designcore, Institute of Technology, Carlow, Ireland
[2]Faculty of Science and Technology, Engineering & Computing, Bournemouth University, England
[3]School of Health and Social Care, Bournemouth University, England
[4]Product Design and Technology, University of Limerick, Ireland

**ABSTRACT**
The social practice of design and design research and is continually evolving to meet the needs of society. Its representation and evaluation in research assessment exercises, such as the UK (Research Excellence Framework) REF 2014[1] has a key role to play in its evolution. Higher education curriculum is affected by this type of representation due to the alignment of academic research inquiry. This paper examines through a documentary analysis of the REF 2014, the practice of funding evaluation exercises to discover and describe how they work and to provide a critique of those practices, using critical discourse analysis. By using Fairclough's[2] three dimensional framework for examining discursive events, it is possible to explore the "relationships of causality and determination"[2] between discursive practices (the evaluation and subsequent funding of UK Higher Education research) and texts (REF 2014) and the wider social and cultural structures and processes which are influencing and being influenced by it. The analysis reveals the considerable influence of REF 2014 in the discourses of other stakeholders and the dominance within those discourses of market system structures where accountability, public relations and intense competition are fundamental to their operation. It raises questions about the nature of research assessment exercises, their ability to reward a diverse range of research in a fair and equitable manner and the impact of research assessment exercises on research inquiry, academic freedom and originality in universities.

*Keywords: Product Design Representation and Evaluation, Product Design Education, Higher Education Research Funding, UK REF 2014, Critical Discourse Analysis (CDA)*

## 1 INTRODUCTION
The social practices of design and design research and education are continually evolving to meet the needs of society. Product design with roots in craft and experiential learning has become an increasingly complex interdisciplinary activity working with new and emerging technologies, borrowing and adapting research methodologies from a range of disciplines including pure and applied sciences, social and behavioural sciences and the humanities in order to address these social needs. It is important that within this evolution, design research within and outside the university develops in line with social need and that we as academic design researchers and educators are mindful of the forces guiding this evolution, as reflected in the aim of this conference;

> "it is important that design educators explore interrelationships between engineering & technology, and behavioural, societal, cultural & ethical issues."[3]

The representation and evaluation of design and research in the public sphere has a role to play in its evolution. Research assessment exercises, such as the UK REF 2014[1] allocate research funding based on its assessment. They also provide bench marking information for universities and accountability for public investment in research. The UK REF 2014 documents inform and provide evidence for claims made by government, funding bodies, universities and the media regarding the nature and quality of research in the UK hence the significance of examining the explicit and implicit values in the UK REF 2014 through a documentary analysis.

## 2 METHODOLOGY – CRITICAL DISCOURSE ANALYSIS (CDA)

Critical discourse analysis (CDA) is trans-disciplinary, connecting linguistic and social analysis. It focuses on the part language and discourse play in social maintenance and change. A Critical Discourse Analysis of the UK REF 2014 can help raise awareness of what is going on in that exercise and "whether it maintains the existing social structure or is likely to change or revise it"[4]. The Critical Discourse Analysis adopted here is based on Fairclough's three-dimensional framework for analyzing discursive events [2]. It aims to

> "explore often opaque relationships of causality and determination between (a) discursive practices, events and texts, and (b) wider social and cultural structures, relations and processes; to investigate how such practices, events and texts arise out of and are ideologically shaped by relations of power and struggles over power; and to explore how the opacity of these relationships between discourse and society is itself a factor securing power and hegemony" [2].

Social practices and their definitions are fluid and evolving, none more so than that of design and its alignment with research and education. It is important to understand the mechanisms and processes that influence this evolution, if we are to influence change. "This accords with the critical intent of this approach, the production of knowledge which can lead to emancipatory change."[5] Fairclough [2] outlines how

> "each discursive event has three dimensions or facets: it is a spoken or written language or text, it is an instance of discourse practice involving the production and interpretation of text, and it is a piece of social practice".

These are three complementary "ways of reading a complex social event."[2]

> "The connection between text and social practice is seen as being mediated by discourse practice: on the one hand, processes of text production and interpretation are shaped by (and help shape) the nature of social practice, and on the other hand the production process shapes (and leaves 'traces' in) the text, and the interpretative process operates upon 'cues' in the text" [2].

For the purpose of this study, the text is the UK REF 2014; the discursive practice is the evaluation and subsequent funding of UK Higher Education research by the Higher Education Funding Council for England (HEFCE). An outline of the wider social practice would include a neoliberal political background, a public sector and a university system which is increasingly being subjected to the forces of marketization and commodification, a dominant positivist/empirical research discourse and an opposing design research discourse.

> "Discourses, frequently based on the norms of a group, exclude and devalue the norms and practices of other groups and, therefore, dominant discourses wield power."[6]

In the case of the UK REF 2014, this has very real implications, in terms of gaining access to funding, public esteem, and also its potential influence on the development of research in particular niche areas such as design, as researchers modify their ideal practice to attain funding. A critical discourse analysis of the UK REF 2014 will illustrate how research is represented and evaluated by the UK higher education funding bodies and whether this representation and evaluation of research is capable of identifying and fostering research excellence in design and other niche areas. Other groups such as the research users, industry, Business, Innovation & Skills (BIS) research councils, UK government local health and hospital authorities and UK charities, also conduct practices which shape the representation and evaluation of research in the public sphere but these will not be considered in this particular study.

## 3 DOCUMENTS FOR CRITICAL DISCOURSE ANALYSIS

As there are many long documents explaining the REF 2014, it was necessary to select a representative and appropriate sample for analysis. The REF 2014 website home page was selected for CDA as it is the first point of contact for all stakeholders and provides an overview of the assessment framework [1].

A study of two documents;

> REF 02.2011 Assessment framework and guidance on submissions (July 2011) [7] and
> REF 01.2012 Panel Criteria and working methods (January 2012) [8]

was necessary to understand the evaluation process; the generic assessment criteria and the assessment criteria for the Unit of Assessment 34: Art and Design: History, Practice and Theory. As both are long documents, (63 and 106 pages respectively), the sections concerning the evaluation of design research were selected for analysis, that is generic criteria and criteria specific to UOA 34. These were dispersed throughout both documents. Page locations will be referred to in the analysis.

## 4 DISCURSIVE PRACTICE

The network of practices which shape the representation and evaluation of research in the public sphere include;

- Government and party politics, public information documents and public relations documents e.g. political manifestos, speeches, reports, leaflets, posters.
- UK Higher Education funding bodies, public information and public relation documents, e.g. websites, leaflets, reports, press releases, posters.
- Mass media, e.g. television, newspapers, websites, posters.
- UK Universities public information and public relation documents and research and education material, e.g. web sites, prospectus, advertisements, academic papers, lectures.

The REF 2014 documents inform and provide evidence for claims made by these four spheres of influence and associated stakeholders regarding the nature and quality of research in the UK. It is a resource for producing further reports and texts as outlined above. By referring to the UK REF 2014, these stakeholders can demonstrate the benefits of public investment in research, account for their position and the quality of their work and in the case of universities, bench mark their research relative to that of others. This is an indication of the significance of research evaluation exercises for all the stakeholders. It also indicates the importance of securing a positive assessment result for the progressive development of research in emerging niche areas such as design. Poor assessment outcomes in these exercises will impact negatively on research funding, research development, public perceptions and ultimately the nature of education provision.

Accountability and public relations are important in many of the discursive practices listed above which influence how research is represented. The Higher Education Funding Council for England (HEFCE) operates within this realm as indicated by the REF 2014 home page statement [1] that "the funding bodies intend to use the assessment outcomes to… provide accountability for public investment." This is due to the commercial environment education operates in. For example, Bloor and Bloor describe how UK universities have been pressured to operate like commercial companies, competing with each other for business since the 1980s [4]. Within this arena, there is considerable pressure to generate research income. The long established research tradition of science with its claims to truth and its explicit and universally understood demonstration of rigor, reliability and validity help provide predictable accountability for much of the communications in these practices. For example, internationally much of research assessment has an "inbuilt bias in favour of hard sciences and bio sciences" [9]. This bias is partly due to dependence on bibliographic databases of peer reviewed journals, such as Thomson Reuters Web of Science and Elsevier's Scopus, as an empirical basis for research assessment. These are prime vehicles for knowledge dissemination in the natural sciences, medical sciences and life sciences. This is to detriment of disciplines with more disparate publication cultures and varied research outputs, such as the creative arts [9].

There is a presupposition within the documents that the configuration and funding of research should mirror the organization of a market system. For example, research in this document assimilates the characteristics of a commodity in a market or a competitor in a competition. The research that can best prove its worth within the given framework wins. Academic freedom to select and manage research agendas is being restrained by these market values. The home page of the REF 2014[1] outlines how "The REF is a process of expert review… the funding bodies intend to use the assessment outcomes to inform the selective allocation of their research funding." Within the REF 2014, 'quality research' as defined by the REF is awarded greater funding. Competitive language is a significant property of this discourse. There is competition between government parties for votes, funding bodies for validation, UK universities for funding and students, even the media for readership. To compete, it is necessary to compare like with like, to quantify the outputs. There is an element of cost benefit analysis. This process is referred to on the home page "Sub- panels will apply a set of generic assessment criteria and level definitions, to produce an overall quality profile for each submission". [1] The complexity of funding evaluation exercises and the necessity of producing metrics to evaluate research for the purposes of funding can lead to the use of a more quantitative metric (for example citations or research income) which may fail to identify and value more qualitative and contextual research. Traditional research approaches are easier to quantify and compare than the more interpretative or practice based research approaches. Also new or emerging research disciplines or departments are at an immediate disadvantage when seeking funding based on past successes. Given the breath and diversity of the research submitted, it is questionable whether it is possible to evaluate, compare and subsequently award research in a fair and equitable manner. It is probable also that the evaluation criteria will have an influence on how future research is conducted if the researcher hopes to attain funding from this source. To quote Ken Robinson in a government paper on supporting creativity, culture and education for young people;

> "The understandable tendency …. is to respond to what the assessment system values most: and for education as a whole to fulfil MacNamara's Fallacy: 'the tendency to make the measurable important rather than the important measurable" [10].

This may not be the intention of research assessment exercises but it may well be an effect.

## 5 ANALYZING THE TEXT

The primary genre is that of public information document. The REF is a complex system for assessing the quality of research in the UK, by the four UK higher education funding bodies, in order to allocate research funding to universities, from 2015 – 16.

The home page of the REF 2014[1] takes the form of a public information leaflet outlining the purpose and form of the REF. While factual in nature it also has promotional elements. The change of title from 'Research Assessment Exercise' (RAE) [11] to 'Research Excellence Framework' REF may be indicative of the commercial and subsequent promotional requirements of these organisations. It clearly indicates that it will be used for "allocation of funding, accountability for public investment in research and to establish reputational yardsticks" [1]. The homepage page also implicitly promotes and provides evidence for the continued existence of these public bodies. The continued use of the words, excellence, quality and expert imply that the document, the assessment framework, the funding bodies and those allocated funding both value and share these characteristics. In terms of vocabulary, the metaphors used on the home page and throughout the document are consistently chosen from the lexical fields of accounting and bookkeeping "accountability" [1], engineering and land surveying "bench marking, reputational yard sticks" [1] and policing "evidence" [1] reinforcing the themes of quantification and policing within the document.

Research funding exercises play a vital role in supporting and enriching research development in higher education. It is important to consider carefully the impact of the funding model adopted on all research areas and also to consider alternatives. There was a consultation process in the development of the REF 2014 in an effort to attend to the criticism of the previous RAE [11], some of which have been addressed. The previous model, RAE was criticised by Frayling in an art and design research context

> "as a threat to a distinctive pedagogical tradition that involves: …studio or workshop based teaching, an emphasis on tacit knowledge, a focus on individual student projects … rather than on a generalised curriculum, and above all an iterative approach to learning; an action based mixture of the conceptual recognition of problems and their resolution in the form of tangible things…". [12]

The impact of the REF 2014 is yet to be seen but perhaps a more vigorous public debate which takes a step back and considers a range of approaches to research funding and support at foundation level would be useful. Analysis of the REF 2014 documentation creates a less nuanced picture and the previous acknowledgement during the consultation process of possible negative impacts is absent. Grammatically, the document is authoritative and unquestionable in its modality demonstrated by the use of declarative statements such as "will replace", "will apply" and "will be assessed".[1] The implicit message in the documentation is that this is the 'common sense' and 'expert' process of publically funding research. Contributing to altering and possibly fixing this common-sense understanding of how research could be funded and evaluated is the process of nominalisation. Fairclough cited in Lim [13] outlines how

> "nominalisations work to obscure important elements of processes. By expressing a process as a noun, as if it were an entity, crucial aspects of the process may be left unspecified, but tacitly assumed as self-evident and straightforwardly commonsensical" [13].

For example, on the home page of the REF 2014, [1] the process of planning and designing the assessment is absent when it is referred to as "the assessment". This is evident again on the home page where, the people involved in making decisions about research quality are nominalised. "The REF is a process of 'expert review". [1] Here the agent is removed. The process is depersonalized. This has the dual effect of removing both the decision making process, its rationale and the personalities involved from our reading of the document. Ideologically, the implicit message in the document is that a diverse range of academic research should and can be assessed fairly, and that this is the 'common sense' and 'expert' process of publically funding research, References to other mechanisms for funding research which may value more intuitive or empathic forms of research are absent.

The REF 2014 assessment exercise is essentially a reducing process. For the purpose of evaluation, each research submission is reduced to an "assessment outcome" and "a starred quality profile" [7] (pp.43). This is to enable selective allocation of research funding and to provide "benchmarking information and establish reputational yardsticks" [1]. It follows a quantitative procedure of breaking the research down into discrete parts, assessing them individually and calculating the results. These are artificial divisions which decontextualize and fragment the research process and may fail to recognise and value more applied contextual research [7] (pp.43).

The most significant change in the development of the REF 2014 from the RAE 2008[11] has been the introduction of an explicit element to assess the impact of research [7] (pp.44). As outlined in REF 01. 2011, this

> "reflects policy aims across the four UK funding bodies to maintain and improve the achievements of the higher education sector, both in undertaking excellent research and in building on this research to achieve demonstrable benefits to the wider economy and society." [14] (pp.3).

This is a valuable research outcome worthy of recognition. However, it is assessed via a 'case study' which imposes a particular research framework. This increases the pressure on academics to address external prerequisites to gaining research funding and subsequently reduces agency freedom in their research methodologies.

### 5.1 Representation and Evaluation of Product Design Research

The representation of product design research is limited; there is mention of "product design" and "interdisciplinary research" in the UOA 34 discipline listings along with a mention of "designs and exhibitions" but these are only listings and representation is defined by association with the other creative disciplines listed [8] (pp.82). In terms of evaluation, product design research is evaluated by main panel D and its sub panel UOA 34 according to the generic criteria for assessing submissions, as long as it adheres to the generic definition of research as defined in Annex C "as a process of investigation leading to new insights, effectively shared" [7] (pp.48). This is an open and inclusive definition of research. The document does not at any point attempt to define product design research. It does give examples of possible outputs, "designs and exhibitions" [8] (pp.85) being one of them and it provides an overall interpretation of the assessment criteria for the panel D which again seems quite flexible and based on expert review. The document states that panels will "aim to identify excellence wherever they can find it" [8] (pp.79). It is a system of expert review which affords an element of flexibility within the system but also requires a 'leap of faith' to be made by design researchers when submitting their research. On reflection, product design research has a very small voice in the REF 2014 and its assessment is dependent upon the interpretation of the reviewers, within a quantitative assessment framework.

## 6 SOCIAL PRACTICE

Research assessment exercises such as the REF 2014 are part of a broader neo-liberal project in higher education where, following the argument of Bourdieu in Fairclough, social practice and discourse is being restructured "in accord with the demands of unrestrained global capitalism" [2]. This is changing research and educational practice in universities. Researchers are required to be increasingly strategic, organizing their research and educational practice to align favourably with the assessment criteria of research evaluation exercises. Concerns have been expressed by a number of authors on the impact this has on academic freedom and original research [9], [15]. Marginson's nuanced description outlines how,

> "The argument is not that neo-liberalism suppresses academic freedoms, but that it channels and limits academic freedoms. We are not robbed of agency per se, but we are robbed of

certain forms of agency that arguably are vital to creators of academic knowledge in universities" [15].

For product design research, the impact may be particularly significant as CDA reveals that the discourse and research values of product design are poorly represented in the REF 2014. This indicates a conflict exists between the representation and evaluation of research in the discourse of the REF 2014 and in the discourse of product design. This conflict highlights the challenge for product designers to attain research funding in these exercises and the pressure it places on them to modify their research practice in accordance with the values expressed in the REF 2014.

## 7 CONCLUSION

This CDA of the REF 2014 illustrates the wider social and cultural structures which are influencing the representation, evaluation and continued evolution of product design research. The findings contribute to our understanding of these mechanisms and processes and this is important if we are to influence change. As product design is not part of the dominant discourse within the document, it may impact on its positive recognition and subsequent evaluation. While the REF 2014 provides little definition of design research and excellence in design research output, it may still have a significant impact on product design research and education practice. The findings suggest exercises, such as REF 2014, designed to support research need to be developed with care and to consider intended and unintended impacts they may have on research and education practice.

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# NEW DESIGN IS BIGGER AND HARDER – DESIGN MASTERY IN A CHANGING WORLD

**Mark BAILEY, Mersha AFTAB and Trevor DUNCAN**
Northumbria University, Newcastle Upon Tyne

**ABSTRACT**
Design-led, transformative innovation, with social or commercial value, is achieved through an increasingly complex and diverse spectrum of contexts requiring a broad range of specialist knowledge and skills. Delivering such innovation is rarely a solo-act. It is collaborative and multidisciplinary. Such innovation capitalises on scientific and technological discovery as well as business know-how and context-specific specialist knowledge all given meaning through design. At its best, it redefines the way we live, the way we create value and the way we craft our future selves. It relies on both individual growth and a willingness and ability to work with others to venture into the unknown.
The traditional models of design mastery, however, focus on the development of advanced level individual knowledge and practice. This paper establishes principles for Post Graduate education in Design Innovation within the context of design's changing and expanding role.

*Keywords: Design, Masters, New Mastery, Design-led Innovation, Innovation Design*

## 1 INTRODUCTION

The roles of the designer and the design disciplines have changed over the decades as the practices of design have evolved and the social, cultural and political contexts in which designers have operated have shifted. The likes of McCullagh [9], Gardien & Gilsing [8], Verganti [16] and Yee, Jefferies and Tan [17] have all charted changes in the role and influence of the design function for organisations [2]. The changing nature of design itself has been additive; the development of new tools for designers has arguably meant little reduction in the usefulness of the 'old' tools. Similarly, the changes in territories and context have required acquisition of new knowledge and skills in addition to those that are core to traditional models of design. The new models of design need to address these bigger trends and transformations. The authors reflect on the implication of this on design education and propose ways in which it could respond to this changing landscape.

### 1.1 Background and methodology

Currently the suite of MA Design programmes at Northumbria University comprises education in design management and design (with specialisms in industrial, fashion, graphic, performance products, service, interior design etc.). Although these programmes provide students with the ability to reflect and apply knowledge in their individual contexts and specialisms, the opportunity exists to better align them to the needs of contemporary design theories and practices. Operating alongside these is a cross-faculty programme in multidisciplinary innovation. Determined from literature, direct engagement with employers and users of design and through an auto-ethnographic and semi-structured interview approach the authors have reflected on these programmes and explored the gaps between what they offer and what masters of design in the future will need.

## 2 STARTING POINTS

Jonathan Ive is famously quoted as saying *"Design is not important. Good design is important."* And whilst it is hard to argue with this, it is worth considering what we mean by good design, and whether good design on its own is enough. We are all familiar with good designs that have been commercial flops or failed to deliver the societal benefit that they promised (Microsoft web TV plus; Betamax, Sony; The Newton, Apple; Cocaine, Redux Beverages; eVilla, Sony, and Pippin, Apple/Bandai etc) because they haven't been supported by the appropriate, sustainable business model, manufacturing capability or delivery strategy required to enable them to flourish. Traditionally, design in isolation is seen to provide a service to new product development but today this position of design is being challenged. Recent research in mapping innovation practices in multinationals confirmed *"it is possible to operate as an individual but the complexity of today's issues is making this very difficult for inventors. The concept of a designer working in a garage and making sense of form and function has been transformed into multidisciplinary teams where we see designers working with physiologists, engineers, scientists etc."* (p. 81) [2] Hence, good design alone is of little value.

Berkun [5], defines innovation as delivering 'significant positive change' whilst another popular definition [6], suggests that it is 'bright ideas realised'. Taken together, we can see a role for design in these definitions (through the creation of ideas), but we can also see gaps in what design has to offer in terms of 'change' or 'realization', which rely on a complex interplay of context, specific factors if they are to be achieved. Press & Cooper [12] agree that innovation in new products and new markets is most important for top executives. Therefore, it is unreasonable to expect that designers acting alone, could make a significant contribution in the delivery of change other than in the creation of beautifully resolved ideas. It is even more unlikely that a young designer with only a Bachelors degree, often achieved in isolation from the real-world demands of business, could affect such change.

Press and Cooper (2003, p. 17) [12], state that *"...Design and innovation are complementary, design being a core element of technical or product innovation yet also broader in its influence on product. Innovation is also broader than design in terms of management areas in which it can occur alone. Together design and innovation are in effect the drivers of any successful business".* For design to have relevance in society, its purpose and application must surely be the creation of 'significant positive change'. It follows, therefore, that design education's focus must shift to encompass innovation. We must adjust our focus to Design Innovation. And, we have established that innovation relies upon a mixed discipline collaborative approach; this in turn means that new mastery must promote multidisciplinary cooperation as well as the development of personal, discipline specific expertise.

### 2.1 Design Innovation Education

Bachelors education for designers is relatively mature, the 'Competency Model' developed and described by TU/e [14] is indicative of that which is covered by many of the more established undergraduate programmes which focus on the development of knowledge, skills and attitude achieved through practice and demonstrated through projects. These are given relevance by the context of application, in the best cases through interaction with real-world situations through 'live' industry-linked projects and internships. These curricula generally have a fairly narrow 'band-width' focusing on specific design disciplines; Industrial Design, Fashion Design etc. In the case of TU/e, this is Industrial Design Technology.

This brings us to the role of post-graduate education in Innovation Design. Typically, the designer who attains mastery in their chosen design subject demonstrates this through their graduating, or dissertation, project; their 'masterpiece'. When the context of application has a narrow bandwidth such mastery is comparatively easy to identify and assess. For example, a master designer of furniture can demonstrate their mastery by value-creation in the production of multiple designs of chair suited to multiple use scenarios exploiting a variety of materials and production methods (Innovation). Through their designs they may express new design processes, knowledge and know-how (Research). The chair will represent a tangible manifestation of their tacit knowledge, demonstrating what they know about how they think with both their head and their hands (Reflection). A challenge for Mastery in Design Innovation is that it requires a broader expression, connectivity with other disciplines, methods, approaches and contexts, making the masterpiece less readily interpreted.

### 2.2 The Designer Innovator

As the importance of innovation has increased, so too have the descriptions of the designer as a letter-formed individual; T-shaped, X-shaped, Y-shaped; have all been tried. These descriptions have all acknowledged two things; the increasing need for designers to have the ability to collaborate across disciplines, and the importance of deep, core knowledge. McCullogh [9] in exploring the notion of the T-shaped, identified a need for designers to ensure that they have a strong 'vertical stack' before venturing too far into the domains of others through their horizontal reach (within the educational setting, one could argue that this is the role of a good Bachelor degree in establishing core design competencies). Neumeier [11], whilst acknowledging the important role that 'T's' have to play, extolls the virtues of the 'X-shaped' individuals who connect and lead. Importantly, he stresses the importance of the individual's strengths and the development of their personal, high-level 'meta-skills'; "*Whether a T or an X, you still have to develop your own skills, create your own thought processes, and spend time alone in the "dragon pit" – the space between what is and what could be. In the dragon pit, a master's degree won't help you. Only mastery itself*."

This lays down a clear challenge to those who run such Masters degrees. Neumeier's [11] focus on 'self' chimes well with Vanderbilt's [15] adoption of Sinek's [13] Golden Circle, 'What, How and Why' model in proposing the 'whY-shaped' individual. He places emphasis clearly on the individual's purpose (or 'Why') in employing their specific skills and knowledge and in establishing the connections that they make. Sinek [13] is clear that we can only lead meaningful change if we (or our organisations) do so with a clear sense of purpose or set of shared values. Similarly, we have seen in our own research [4] that multidisciplinary team success is only achieved once the team establishes a clear, shared purpose and translates this into a vision before embarking on delivering the vision through creative possibilities.

Supporting the development of clear personal purpose as a designer within the constructs of a clear institutional purpose for design innovation education (delivering significant positive change) is a compelling principle upon which to build.

## 3 PRINCIPLES FOR NEW MASTERY IN DESIGN

Against this changing landscape then, we have established three clear principles:

- Design on its own is not enough; what the world needs is Design Innovation. Our new mastery needs, therefore, to deliver this.
- We know that innovation is dependent upon individuals combining their knowledge and skills with those of other disciplines and that, in order to do this they must learn about themselves in relation to others; they must learn to collaborate and work in multidisciplinary teams.
- Only design innovators with a clear sense of purpose will bring about meaningful change; our programmes need to focus on developing designerly purpose.

The expanding reach of design theories and practices suggests that we need to be able to develop this mastery across a broad spectrum of design disciplines. This spectrum spans from 'design-thinking' to 'design doing' and recognizes the absolute value of the associated range of knowledge, skills and competencies (and the doing in thinking and thinking in doing!). The expression of that output is given relevance by the context in which it is applied – an authentic application in the 'dragon-pit'.

- Context relevance is the fourth principle upon which programmes of Design Innovation should be founded.

### 3.1 Designerly Purpose

At the heart of this new mastery are learners and their developing designerly purpose; as an individual, as a member of an organisation and as a member of society. In considering what dimensions contribute to the developing designerly purpose we can look to Adair's 'task-team-individual' model for Action Centred Leadership [1]. For the individual to develop and understand their purpose as a designer, they need to develop an awareness of their personal values, to test these in context through an established task purpose and to do this in relation to others.

Whilst our individual values may be firmly engrained, our designerly-purpose is not static; it is shaped by our experience and the tacit knowledge we derive from it. Building on Sinek's model, 'How' we express our designerly purpose is important to the development of it through reflective cycles [7] and this is equally relevant whether we are a design-doer, thinker or researcher (or, as is most typical, combination of all three). 'What' we do, establishes the sphere of influence in which our designerly-purpose is manifest. Figure 1 illustrates one such tapestry where the 'why' (purpose), 'how' (design doing/design thinking/design researching) and 'what' (design output) interplays to define the individual value of a designer.

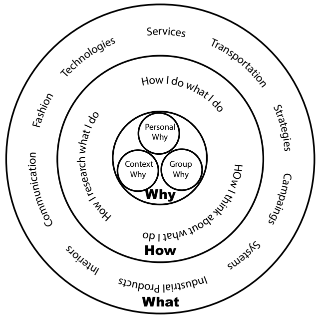


*Figure 1. Illustrating value of a designer (Source: Adapted from Sinek (2013) )*

Acknowledging that our students at Masters level already have their core competencies as designers, what then do they need to learn in order to establish their designerly-purpose and to be able to create a masterpiece suitable of demonstrating the mastery that would satisfy even Neuemier [11] and, more importantly, equip them to affect significant positive change for the betterment of society (our purpose!)?

## 4 CONCLUSION

The influence of the changing landscape of design has caused us to reflect upon Masters education in design. We have concluded that, in order to nurture graduates who can bring about significant positive change we need to focus on the development of their individual designerly purpose and provide them with the contexts within which to explore and demonstrate their mastery of Design Innovation. Therefore, we propose the application of the above stated principles and the following key knowledge blocks as required for the delivery of new mastery.

### 4.1 Key Knowledge for Design Mastery

Simplistically, we can think of Innovation Design mastery existing on a horizontal doing-thinking spectrum where the students (design doers/design researchers/design thinkers) learn with and from each other (Figure 2). The horizontal spectrum provides the context situations through which they develop and demonstrate their mastery.

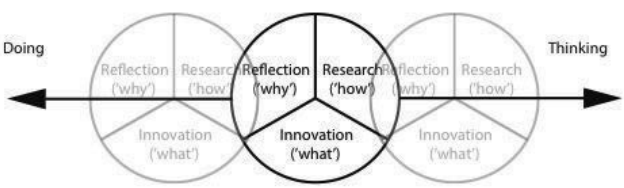


*Figure 2. Doing-thinking spectrum*

Irrespective of where they position themselves on the doing–thinking spectrum, the three knowledge blocks of Innovation, Research and Reflection will underpin their study and deliver the principles.

1. Reflection will underpin the students' purpose, their 'Why' in relation to themselves, their discipline and their colleagues. It will provide an understanding of themselves in relation to those with whom they work and in relation to their own learning and development, their values and behaviours. It will promote a hunger for continual personal development.
2. Research will support the 'How'; the curiosity to identify what new knowledge the masters student needs in order to complete the task at hand; the knowledge to create and execute a research plan that enables them to access the data that will provide that new knowledge; the capacity to synthesise that data into meaningful insights and the creativity to apply those insights to give meaning to them.

3. Innovation will deliver the 'What' in the context of application. It will deliver value-creation through the ability to make connections and collaborate, advanced creativity and strategic thinking and the leadership potential to turn ideas into realised solutions.

These core knowledge blocks are relevant to the designer anywhere along the spectrum, but they have little value unless they are exercised in context relevant to the individual. And none of this is worth a thing, unless they are tested in the 'dragon-pit' of real-world situations. For this reason, students pursuing new-mastery, at any point along the spectrum, will work collaboratively with each other and with commercial partners. Previous research with Design Innovation students [4] established the value of addressing business challenges rather than design briefs in pursuit of innovative solutions and this is very much the case here; anchoring the creative practice in a real-world context where its value can be measured.

### 4.2 Assessing New Mastery

The linear model presented above is, of course, far too simplistic. Contexts of application will span the doing-thinking spectrum and students' will develop their mastery in a 3-dimensional way dependent upon their own designerly purpose and an individual learning contract. Assessment has to reflect this and this is where a Portfolio of Practice [3] supported by a learning contract comes into play. Already in use at Northumbria University, the Portfolio of Practice provides students with the opportunity to provide a factual account of what has been done and to reflect upon what has been learned as a result. The learning contract, agreed with specialist academics with expertise in the discipline relevant to the student, is informed by the requirements of the context of application.

### 4.3 Impact

Understanding the impact and currency of our knowledge helps us assess the Mastery of students. The core of the knowledge required to support this assessment model is both robust, stable and industry relevant having been developed and refined through our existing programmes and research. It is continually refreshed and validated through the direct engagement that our students, academics and alumni have across the design disciplines and sectors.

The impact of the knowledge that we share can be seen in the changes that our alumni affect and the careers that they enjoy. It does not end at graduation; their knowledge is developed further through professional practice and comes back to us through collaborative projects, research activities and return to study at doctoral level for some of our graduates.

These fundamental principles for New Mastery are as relevant to our programmes, where they are, in part, already being piloted, as they are for other institutions and practice-based subjects. Masters who know themselves, their discipline and how to create value through this knowledge by working with others hold the key to significant positive change.

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Chapter 10

# ETHICS AND EMOTIONS

# POSITIVE ETHICS IN DESIGN EDUCATION

**Marina Henrieke SONNEVELD**
Department of Design Aesthetics, Faculty of Design Engineering, Delft University of Technology

**ABSTRACT**
Technology has a strong impact on the way we live our lives, on our behaviour. Technology seems thereby to be a strong factor in the ethical aspects of our daily live. Being aware of these aspects is part of the responsibility of the designer. Experts in Ethics of Technology support designers in developing this awareness. However valuable this support is, designers may perceive this approach as restrictive rather than inspiring. Moreover, this approach may be perceived as insights enforced upon them rather than as felt from within. This paper explores how the development of ethical awareness in design education can be addressed from a positive perspective, exploring the personal frame of values as a possible starting point for ethical reflections on designing.

*Keywords: Positive Ethics, personal values*

## 1 INTRODUCTION

Reflections on the ethical dimension of product design can be considered at different levels of designing. First, one could consider universal ethical principles that should apply for all humans, as for example formulated in the declaration of human rights. Next, at a societal level, one could consider the effect of design and technology on the intended users, and consequently, on how one should design to optimize this effect, or at least, to minimise harm. Next, form the perspective of professional practice, designers could formulate code of conducts, as is now being developed by several design organisations. What these approaches have in common is a top down approach: ethical reflections and perspectives are developed by experts, hoping that designers will comply, and take the proposed perspectives as their perspectives. The value of experts reflecting on the ethical domain of designing, and proposing possible insights to take into account when designing, is evident and relevant, and should be supported and welcomed. However, it may also present two obstacles for a fruitful connection with the design world.

First, ethical reflection in design, considering values such as wellbeing, safety, autonomy, responsibility, and so on, is often a theoretical perspective: focussed on abstract users and abstract use situations [1] [2] [3]. Although illustrated with concrete examples, the theory remains theoretical, searching for a general position a designer should develop towards users. Moreover, ethical theories often focus on the user, and less on the designer being a person himself. One could argue that this position creates a distance between the designer as a person, with his own personal, ethical values, and the designer as a critical thinker on the effects of his design. This distance may be fruitful and enriching when the designer succeeds in bridging this gap. Yet it may also have a negative effect, leading to designers who do not feel committed as a person to the values they are trying to design for, their designs thereby becoming superficial or even inconsistent. A first concern is therefore that professional ethical insights not always take into account the designer as a person, with his own identity, values and concerns. When designing, one not only operates with a focus on the ethical aspects of the effect on the user. One also operates from one's personal framework of moral values in life. Yet, this personal framework is often implicit, one is not aware of it. It is shaped by factors such as culture, education and personal experiences. The design starting points it generates are then taken for granted, rather than critically reflected upon. Becoming aware of this framework, by making it explicit, allows designers on the one hand to critically reflect on it, possibly changing it or fine-tuning it, and on the other hand to be inspired by it. One's personal set of ethical values may prove to be a valuable guideline when designing. It is therefore important and valuable to make design students aware of the ethical values they take into account when designing, as well as the ones they live by.

A second concern is that given this top-down approach, ethics may be perceived as restrictive, as a cumbersome aspect one would rather not deal with, but has to. Much like sustainability issues were seen as cumbersome in the first days of sustainable design. For example, the Delft University of Technology is now working on an ethical code when it comes to involving users in design research, asking students to submit their research proposals to an ethical committee. A pitfall may be that by introducing this ethical code as a set of rules to comply to, students do not see ethics as a potential source of inspiration but as something one hopes to be able to avoid or 'get around'. Yet, also in the case of design students setting up their project, considering the ethical aspects may be seen as a great source of inspiration, as several initiatives in the domain of value-centred design has shown [4] [5].

The challenge in design education is to explore how ethics can be stimulated and supported from a positive and bottom up perspective, rather than from a top down and restrictive one [6]. Next, to stimulate students to perceive ethical reflection as one of their personal concerns, and to show them that their personal ethical values are an inspiring source of inspiration for their professional design practice.

The aim of this paper is to explore how creating awareness, and stimulating discovery of personal values, could be integrated in the development of professional ethics sensitivity in designing, by using the principles of positive ethics. First the paper will present the principles of positive ethics in the domain of psychology and discuss its relevance for designing. Next it will present the results of an assignment done with 45 master design students, who were asked to explore their personal values in daily life. The paper will conclude on how to develop further the notion of positive ethics in designing, focusing of the necessity of an overall vision and accompanying tools and methods.

## 2 PROFESSIONAL ETHICS: POSITIVE VERSUS REMEDIAL ETHICS

The search for a positive paradigm in ethics in professional practice, as opposed to a restrictive one, led to the insights developed in the domain of practical 'positive ethics' in psychology [7]. The starting point is that ethics should not be about 'avoiding doing the wrong thing' (referred to as remedial ethics), but about 'aspiring to doing the right thing', 'to do the best thing to do'.

### 2.1 The principles of positive Ethics

Table 1 gives an overview of the differences between remedial and positive ethics, and the impact on professional behaviour. Although these differences are developed for the moral domains of psychologists, these differences could be developed for design practice as well. For example, the concern for 'informed consent', relevant for designers involving potential users in their design research, is inspired by 'avoiding legal problems' from a remedial ethics perspective. From a positive ethics perspective, it would be inspired by 'striving to ensure an optimal participation of the user, whilst protecting his/her integrity'. In this paper, only the principle of positive ethics is presented, A next step would be to create an overview of the moral domains of the design profession.

*Table 1. Remedial Ethics versus Positive Ethics. (KnappS.J. & VandeCreek, L.D.[1])*

| **Moral Domain** | **Remedial Ethics** | **Positive Ethics** |
|---|---|---|
| Nondiscrimination | Avoiding discrimination | Promoting understanding and appreciation of traditionally disenfranchised groups. |
| Competence | Acquiring and maintaining minimal formal qualifications. | Striving for highest standards of self-competence, including, self-awareness and self-care. |
| Boundaries | Avoiding boundary violations especially sexual exploitations. | Striving to enhance the quality of all professional relationships. |
| Informed Consent | Fulfilling legal responsibilities such as ensuring that patients sign an informed consent form. | Striving to maximize patient participation in development of the goals of the evaluation or therapy. |
| Confidentiality | Avoiding prohibited disclosures | Striving to enhance trust. |

### 2.2 Personal versus Professional ethics: the Acculturation model

One could state that remedial ethics are based on the ethical professional codes that are developed for ones profession. Ethics is reduced to applying and complying to predefined ethical principles and codes of conduct. In positive ethics, in addition to the basic starting points offered by remedial ethics, one develops a professional ethics that reflects ones professional aspirations. Because of this aspirational dimension, professional ethics have a personal 'touch'. Positive ethics asks professionals to be aware of their own, personal ethics, the personal values one lives by. It is important that these personal ethics are made explicit, and that a professional is able to see the link as well as the boundaries between the two. Table 2 gives an overview of the possible consequences badly integrated personal and professional ethics. Again, although the table gives an overview for psychologists, it may be translated as relevant for the design domain. For example, a designer that has high standards in designing, but lacks a personal ethic, may become dogmatic, and vice versa, a designer lacking professional ethics and relying only on personal ethics, may lose sight of his social responsibilities and become over-empathic with a specific group of users at the cost of other people exposed to the product.

*Table 2. Personal ethics in relation to Professional Ethics, viewed as an acculturation model. (KnappS.J. & VandeCreek, L.D.[1])*

| | Professional ethics: High | Professional ethics: Low |
|---|---|---|
| Personal ethics: High | **Integrated**<br><br>Professionally informed; guided by personal compassion; highly effective psychologist. | **Separated**<br><br>Personal compassion not restrained by professional ethics; may get over involved. |
| Personal ethics: Low | **Assimilated**<br><br>Adopted professional standards, but lacks compassion; may become rigid and legalistic. | **Marginalized**<br><br>Low professional and personal standards; risks becoming exploitative. |

To conclude, the presented two insights, first the aspiration to ‘do good the good thing’ rather than to avoid ‘doing the bad thing’, and second the need for a personal ethics, offer a promising starting points for the explorations of the potential of positive ethics for designers, to be developed in the future.

# 3 POSITIVE ETHICS AND PERSONAL VALUES IN DESIGN EDUCATION

## 3.1 Opportunities in design education

In the Master Design for Interaction, the course Reflection on Designing confronts students with the question ‘who are you as a designer? ‘. With aspects such as what they stand for, what inspires them, what methods they use and so on. Early editions of this course showed that students find it easier to reflect on ‘design in general’ than on themselves as designers, but once they feel connected to the goal of the course, tapping into their personal design stand points is experienced as inspiring and empowering. Moreover, students wonder why these questions are not addressed right at the start of the curriculum, rather than almost at the end, before graduating. This fits the Positive Ethics perspective: it is not a code of conduct, to be learned as a separate aspect of design ‘to apply’, but an integrated aspect of designing. Much like attention for ergonomics, for aesthetics, for sustainability is, thus as an integrated skills of designing, to be developed *in* designing. However, we have to start somewhere, and the course reflections on designing seem the right platform to explore positive ethics. In this context, the following paragraph will describe a specific exercise to explore the students’ personal values they live by, and the relevance for their designing.

## 3.2 First explorations of Personal Values

Finding one’s personal frame of values is not an easy task. Autobiographical reflection is considered a fruitful source and starting point. This includes reflecting on memories of experiences in designing, but also on behaviour and experiences from one’s personal life, from childhood until the present day.

After considering personal creative experiences and personal memories, the design students were asked to create their personal framework of values, and next, to indicate how they see these values related to their design work. For this paper, the values they described were clustered as shown in table 1, to get an overview of what kind of values students would put forward.

The personal values the students reported (table 1) reveal values that one does not think of when focusing solely on the profession of designing, or more specifically, on the people who will be using or exposed to the designed products or services. For example, next to expected values such as altruism, social responsibility, and justice, students report the value of being loyal, honest, optimistic, curious and adventurous. These values introduce refreshing nuances of the afore-mentioned social ethical values.

Moreover, it shows that values are not only related towards ‘the other’, towards feeling responsible for the other, taking care of the other, but also towards the self, being aware of personal needs and taking care of the self. For example, students report the value of ‘enjoying life’, of being meaningful, of family and friends. Some descriptions of these values seemed like a personal manifesto, as values never to renounce, whatever one is doing.

After the course, discussions with students revealed that exploring these personal values proved to be an enriching experience and inspiring on different levels: first, as a way to enhance self-awareness and self-care when designing; second, as a source of inspiration to elaborate on one’s design identity which is useful when creating one’s portfolio or designers’ profile. Finally, it is a source of inspiration when actually designing, and engaged in a specific project, not only for the design process per se, but also in the process of design research when communicating with potential end-users – knowing one contributes to the self-confidence to engage in a dialogue with others and, thereby, deepening the users insights.

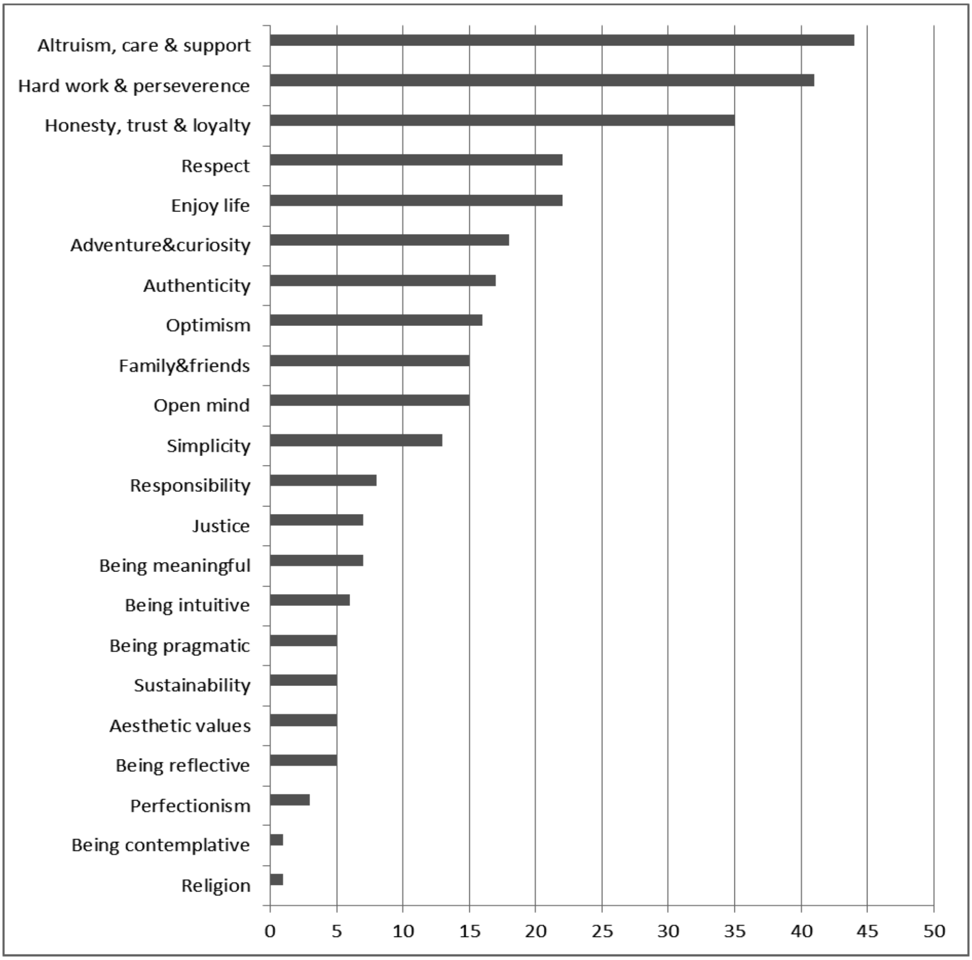


*Figure 1. Personal Values Reported by Design master student (n=45)*

## 4 CONCLUSIONS AND FUTURE DEVELOPMENTS

We started out this journey to explore how to create awareness for ethics in de sign education in a positive way: as inspiring and to aspire for, rather than as restricting and to be bothered by. Two directions seem fruitful: to be inspired by the thoughts of Positive Ethics developed in psychology, and to develop education for students to be able to develop their personal frame of values in life.

The next step would be to be more systematic in these explorations, to develop tools and methods to strengthen the exploration of personal values and their benefits to the designer and his design process [8] [9], whilst keeping this an mind, that is, without trying to categorize it a priori and thereby making it limitative. This can be considered as the need for the development of a new vision on ethics in design education.

### 4.1 The need for tools to create insights in personal ethical awareness

The assignment to explore one's personal values is based on explorations of autobiographical experiences. It is not about making up one's mind about what *could* be a personal value, but about what *proved* to be a personal value. This approach seems to work well, and should be starting point for further development of the assignments. However, the current assignments did not support the students to make the connection with the values one has when exerting the *profession* of designing.

Also, the students report that the link to the professional practice is difficult to make. It is therefore recommended to develop additional assignments, tools and methods focused on the integration of personal values into the professional domain. This will be the challenge for the next edition of the course 'Reflection on Designing'. For example, by developing an overview of the moral domains of the practice of designing, much like the moral domains of psychology presented in table 1.

### 4.2 The need for a vision on ethics in design education: positive ethics in designing

In congruence with the need for additional tools and methods to develop awareness for personal and professional values in designing, there is a need for a positive vision on ethics in designing, a vision that supports students and inspires them, rather than intimidating them or restricting them. Positive ethics seems to offer an inspirational stance for such a vision. To develop this vision, the first step is to create a supportive basis, this development should therefore happen in dialogue with the different stakeholders: the students, the educators, and the experts in the field of professional ethics. Figure 2 shows an overview of the different layers to consider when developing such a vision.

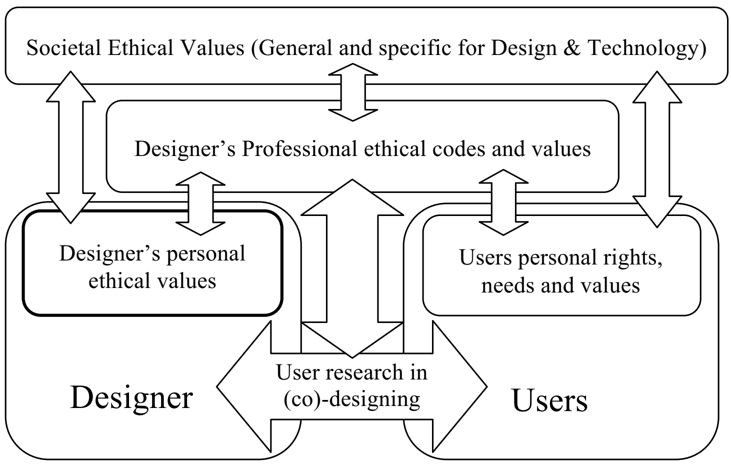


*Figure 2. The position of personal ethical values of designers in relation to professional and societal values, as well as to the values of the people one is designing for*

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# CAN FOLDING A PRODUCT FOSTER EMOTIONAL ATTACHMENT?

**David MORGAN**
Brigham Young University

**ABSTRACT**
People become attached (and unattached) to products for various reasons. Researchers who study "emotion in design" have discussed the nature of such emotional bonds and the mechanisms by which they operate. Through theory, study and observation, scholars have been able to clarify what product factors foster emotional attachment and what human motivations drive attachment to products.
Products requiring the end user to complete the product to make it whole offer a promising interactive space that could foster affecting connections. The DIY approach has potential for developing a unique product/user attachment during the "assembly required" phase of the relationship. But in order to do so, design students must carefully consider and appropriately anticipate the difficulty, duration and nature of the assembling. We argue that the activity of folding a product into its final form provides a pleasurable and fruitful setting for emotional attachment to occur. Folding, in this initial morphogenic stage, provides an interaction that not only forms the product itself but also can be formative in the development of an emotional connection. We discuss design attachment and valuation theory as it relates to product folding then analyze two examples of a folded product in order to examine the value of the approach in a design studio setting.

*Keywords: Morphogenic folding, self-production, product attachment, design pedagogy*

## 1 SELF-PRODUCTION: ATTACHMENT AND IDENTIFICATION

Attachment to a product refers to an appropriate affectional tie between a person and a manufactured good. The designer's attempt to create this tie is motivated by the desire to create products that develop meaning in a consumer's life. If the connection is strong enough, the consumer may keep the product for an extended period, possibly reducing consumption.

### 1.1 Irreplaceability

One way to measure attachment is the notion of irreplaceability. This means that the object is more meaningful to the owner in some way that makes it different from other identical objects. In one study researchers expected that "These feelings of irreplaceability are likely to form the most important component of attachment, because they are based on the personal, idiosyncratic relationship with the product, whereas other components are mainly determined by the (more distant) producer and seller. Therefore, we expect a tight relationship between measures of irreplaceability and attachment." [1] In fact their research shows attachment is highly correlated with irreplaceability.

### 1.2 Valuation

Another study looked at how self-produced products could lead to increased fondness for the product. Researchers studied the effect on consumer valuation when they assembled IKEA furniture, built Lego sets and folded origami. [2] The study shows an increased valuation effect (IKEA effect) when participants created or partially created their own products. They found this effect occurs in connection with both utilitarian and hedonic products alike; that consumers felt their creations should be valued as if they were experts; and that successfully completing the product was a major determining factor of valuation. The study was concerned with consumers' labor and its effect on their valuation of products. They conclude it is largely the effort applied to a successfully completed project that accounts for the increased liking, and suggest this information has implications for product development, marketers and business organizations more broadly.

### 1.3 Identification

A third study was concerned more specifically with how and why attachment and identification with self-produced products occurs. Researchers conducted studies that differentiated between physical and intellectual involvement of participants in product self-production. [3] In one case requiring prescribed physical tasks to be carried out and in another giving participants more latitude to determine the make-up of the final products. The author's results affirm that only positive production experiences lead to increased valuation of self-made products. Furthermore, that attachment to and identification with such products explains why self-made products are rated more favourably that their off-the-shelf counterparts.

The study found attachment increased when a participant was engaged either physically or intellectually (or both) in production. But that product identification occurred only if intellectual investment was required. They determine that intellectual involvement fostered identification because participants were allowed to creatively express their identity through the product.

## 2 FOLDING FOR ATTACHMENT

We submit that conditions conducive for product attachment to occur could be generated through the process of self-production. Further, the activities of self-production are likely to produce a personal idiosyncratic relationship between the consumer and the product.

### 2.1 Folding Advantages

The technology of folding as an industrial production method is well developed and sophisticated. At the same time, folding as a method of self-production has demonstrable potential. Many consumers are familiar with folding from their youth. Folding is an intuitive and non-intimidating method requiring few or no tools. For some, folding is a pleasant satisfying activity that yields rewarding results. In most self-production situations, consumers would be required to fold non-paper materials to produce a product. This may require a mild degree of adaptation for many because while paper is a commonly folded material, it is not commonly used as a durable product material. However, many foldable non-paper materials come in sheet form and reflect some of paper's folding behaviour. We consider folding a promising method of self-production for these reasons:

1. Familiarity: Most consumers are familiar with basic folding techniques. Many have folded simple objects since their youth, mastering paper airplanes, origami figures and wrapping packages, etc.
2. Intuitive: Folding know-how begins as a natural understanding of basic manipulative actions that can be reinforced through practice until a degree of tacit knowledge is acquired.
3. No tools: In its most essential form, folding requires no tools; only material to fold and hands to do the folding. Some basic tools can be employed to meet specific requirements, but these are generally simple to acquire and use.
4. Low waste: Folding is a transformative process that usually leaves little materials waste. Products can be shipped in a compact form then folded into a final form.

### 2.2 Design Recommendations

The intellectual and physical investment required to fold a product has been shown to produce higher valuations and increased identification. [2] The research investigating attachment suggests an impression of irreplaceability is an important factor in producing product attachment. [1] We reason that through close handling, physical manipulation, and creative mental investment, customers create a product unique to them, distinctive from any other, which by extension could be considered precisely unrepeatable and therefore irreplaceable. We conclude this research demonstrates folding is a promising production method to produce consumer product attachment.

In order for consumers to feel attachment by means of folding, designers ought to carefully consider the folding component of the production. Below are some recommendations for students who wish to design to this end.

#### *2.1.1 Appropriate Complexity*

Researchers found that if participants were prevented from completing the task, or required to undo what they had previously completed, they did not rate the product's value higher. A consumer needs to be able to realistically accomplish the task of self-production. [2] Design students must design for an appropriate level of complexity, construction steps should be clear, assembly should be readily discernable, and the overall process should be suitable for the anticipated consumer. Folding can demand a wide range of skill, some projects are very simple to fold, and others incredibly complex. The folding component must be challenging enough to necessitate an investment level that promotes attachment, but not so challenging or time intensive that the consumer becomes discouraged and is frustrated.

#### *2.1.2 Physical Engagement*
The process needs to involve physical labour. Physical manipulation has proven important because the investment of handwork allows attachment to occur. [2] While folding may not be so physically taxing, it can provide an appropriate level of physical engagement to encourage attachment. The successful completion of a folding sequence requiring skill and technique can produce feelings of accomplishment that naturally lead to attachment.

#### *2.1.3 Intellectual Investment*
Intellectual engagement beyond creating attachment also creates identification. [3] If the consumer is allowed to be involved in the configuration, customization or modification of the product through their own creativity, it gives them the opportunity to express their own identity, and thereby identify with the product. A folded product could have multiple possible configurations the consumer may choose from. Or the folder may be able to modify the pattern to suit his or her needs and desires. The design may place the consumer more or less in control of the final product form. The design student should provide enough freedom within the configuration that the consumer feels some freedom to interpret and express his or her own identity.

#### *2.1.4 Aesthetic Accessibility*
When customers perceive the product as attractive and that they have contributed more to the character of the product, their feelings of accomplishment become an important driver of attachment. The designers of self-folded products need to account for the overall attractiveness of the end product and the likelihood that a commonly skilled consumer could generate a product that would meet their aesthetic expectations.

## 3 FOLDED PRODUCT ANALYSIS
In an effort to validate our four design guidelines, we conducted an informal observation of two groups of design and non-design students self-producing two folded products: a chair and a multi-purpose container. Here we report some salient points of our observation related to our design recommendations.

### 3.1 Real Good Chair
Produced by the U.S. company BluDot (http://www.bludot.com/modern-seating/modern-chairs/real-good-chair-4.html), this chair made from laser-cut steel ships flat and is folded into form by the consumer. Online reviews of this chair were mixed, some finding it difficult to fold and assemble and others said it was no problem.

1. Appropriate Complexity: Both groups were able to follow the directions and complete the folding with moderate effort in about ½ hour's time. One group was surprised they needed to cut the angle gauge themselves from the product packaging. Folding the panels to the correct angle was perhaps the most intimidating requirement, but also the most rewarding step. One said, "Oh, I don't want to mess it up."
2. Physical Investment: Assembling this chair requires a moderate degree of physical effort, if only in the most visceral aspect of bending the large steel sheet into the seat back form. After doing this work, students' felt pleased with the intensity of their effort and the perceived precision of their results. One student said, "I liked that the easiest bends were first so you could get a feel for the harder ones." Another said, "Bending it was hard, we needed three of us."
3. Intellectual Investment: Both groups expressed surprise at the level of work required of them. They felt the weight of responsibility to get it right and also discovered some creativity was required. "We had to actually ***create*** the chair, there would not be a chair back if we did not make it," one student said. Another in her group said "We are being creative. The designer puts trust in the consumer."

4. Aesthetic Accessibility: Most students found this chair intriguing as they studied the unboxed components. “When I realized I had to bend it, I thought ‘this is odd’” After it was complete, one student said, “This is so cool, I want this chair.” Some expressed satisfaction and surprise at the solid feel of the chair in contrast to how it looked in pictures. Several students felt it was different from a typical IKEA product, “Not everything was already done,” one student said, “I made it.”

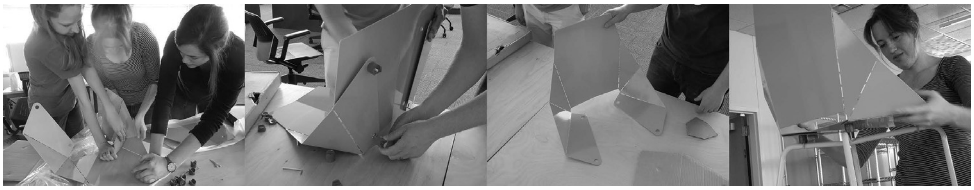

*Figure 1. Student groups folding and assembling the Real Good Chair*

### 3.2 Pres ‘N Thing/ K Do Ding

The Dutch company Coen! produces this product. (http://www.coen.info/en/pres-n-thing) It is a vibrant example of a self-folded product. Consumers receive a flat sheet of waterproof material with a scored tessellation pattern. The included instructions suggest four distinct configurations consumers may fold into shape and snap together.

1. Appropriate Complexity: Although the tessellated pattern initially appears a little complex, the snap connectors were simple to operate and with moderate effort students were able to fold the Pres ‘N Thing in all four suggested configurations.
2. Physical Investment: The Pres ‘N Thing initially ships flat, and the consumer folds each scored line to make the sheet flexible along the fold lines. The time and labour required is moderate and enjoyable.
3. Intellectual Investment: This product requires some intellectual effort to fold any or all of the given configurations. It required engagement to configure, and students we able to express individual identity through configuring the sheet into the range of suggested shapes. Beyond this, the students were able to creatively fold a multiplicity of forms outside of those prescribed.
4. Aesthetic Accessibility: Most students found they were able to create an attractive end product. There was also an aspect of playfulness as students discovered many amusing configurations.

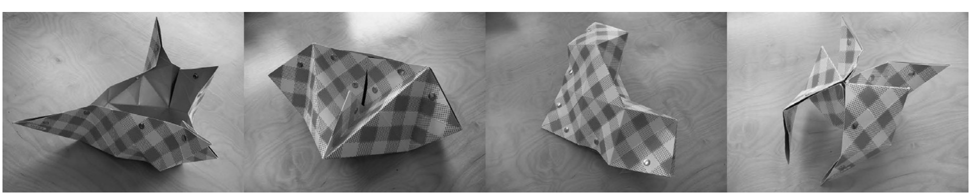

*Figure 2. Pres ‘N Thing folded beyond prescribed forms*

## 4 CONCLUSION

The short answer to the question in the title is “of course”. Studies concerned with self-production have measured the value customers derive from product creation. Our intent here has been to discuss self-production, particularly folding, as a means of not only affecting valuation, but also generating product attachment and connection. By indicating possible connections between product valuation and product attachment scholarship, in the context of folding for self-production, we have perhaps furthered designers’ understanding of guiding principles.

We have also endeavoured to provide practical guidelines for designers and design students that wish to employ self-folding as a strategy to produce products with attachment potential.

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# OLFACTORY CONSIDERATIONS IN DESIGN, A NEW DIMENSION TO PRODUCT EXPERIENCE

**Brecht DAAMS**
Daams Ergonomie, The Netherlands

**ABSTRACT**
Olfactory sense is not often incorporated in ergonomics and product design, even though it is a part of sensory ergonomics jus as sight and hearing are. Technical developments allow nowadays to incorporate smell in many different products. As smell can influence experience and sense of smell has several functions, it is worthwhile for designers to know about olfactory sense and how to design for it.
In this article, an overview is given of the olfactory system and its characteristics. Information is supplied on how to design for various goals, e.g. to prevent, mask, disperse or control odours, to attain congruous smell and taste, to prevent allergies, to transfer information and to influence emotions.
A product should smell congruent to its material, function and context, unless the designer deliberately wants an incongruent smell. Odour can be a powerful instrument to influence emotion and reflexive reactions, but it is difficult to put this use into practice because the reactions to olfactory signals are often determined individually. On the other hand, odour can be used very effectively to give warning in some situations. Attention must be given to fragrance allergy, which affects up to 9,7 % of the population. This percentage is rising, allegedly because of increasing application of fragrances. Application of fragrances in public areas is advised against. The conclusion is that designers should spend conscious thought on olfactory factors in a product. Education presents a good opportunity to advance in this relatively new aspect of design.

*Keywords: Olfactory sense, design for olfaction, smell, odour, allergy, design for babies*

## 1 INTRODUCTION

Olfactory sense is not often incorporated in ergonomics and design, even though theoretically it is part of sensory ergonomics just as sight and hearing. Modern man is interested in body odours and the scent of food, but not in the smell of products around him. Everything has a smell though and products smell, too. Some materials are renowned for a particular smell, like leather or wood. But even olfactory uninteresting materials like iron, paper or plastic can have their own smell. Smell is a source of information which can be quite intrusive.
Sense of smell has several functions which are essential for survival. By smell, the quality of food, drink and air can be assessed. Social signals are unconsciously exchanged by smell. Other animals can be detected, which is important to both predator and pray. Smell may set off reflexive reactions, like mouth watering on the smell of nice food. These qualities make smell an interesting sense to designers.
In this article, first the olfactory system is described and the working is explained. Next, several ways to design for olfaction are described. This article is based on information from the Dutch product ergonomics handbook [1].

## 2 THE OLFACTORY SYSTEM

A short overview will be given of the anatomy of the nose, the working of the olfactory system and the connection between smell and taste. The characteristics of smell will be indicated, as well as the amount of variation between individuals and the variation due to various causes like aging and illness.

### 2.1 Function of olfactory sense

Olfactory sense has four important functions. The most essential function is assessment of inhaled air and ‘tasting’ food and drink. Taste is to a large extent supported by the olfactory system, because the taste categories that can be discerned by the tastebuds in the tongue are limited to sweetness, sourness, saltiness, bitterness and umami. Combination of primary taste with smell enables humans to discern thousands of flavours.

A second function of olfactory sense in the animal world is bonding with others from the same species. Mothers and children of many species can recognize each other by scent.

A third important function is olfactory recognition of prey by predators and recognition of predators by prey animals. Though humans do not have to hunt for breakfast any more, this function is still useful to them: the smell of food makes the salivary glands start working and the saliva assists digestion of food.

The fourth function of olfactory sense is to influence our subconscience, obviously without our notice. This is mediated through pheromones. A pheromone is a secreted or excreted chemical factor that triggers a social response in members of the same species. It can impact the behaviour and/or physiology of the receiving individual. There are various pheromones and each conveys its own message, for example about alarm, food trails, sex and many more subjects.

For a long time it was assumed that humans are cognitive higher beings who decide consciously and are not under the influence of a primitive 'animal' sense like olfaction. Research, however, has since confirmed that pheromones do influence human behaviour, e.g. humans base their partner choice unconsciously partly on body odour, such that their immune systems complement each other.

## 2.2 Anatomy and working of the olfactory system

From an evolutionary point of view, the olfactory system is the oldest of the sensory systems. At birth, olfactory sense is the best developed sense in humans. The olfactory system consists of the nose, the nasal cavity, the olfactory sensors and the olfactory nerve, see Figures 1 and 2.

### *2.2.1 The nose and nasal cavity*

The main functions of the nose and the nasal cavity are cleaning, heating and humidifying of inhaled air and the perception of odours. Odours consist of chemical compounds that can be detected by the olfactory sensors. In humans, these sensors are located in the nasal cavity.

The nasal cavity, see Figures 1 and 2, extends from the surface of the face to the back of the throat. In the nasal cavity are both on the left and the right three thin, symmetric, slightly curled bone plates or *conchae*, which are covered with mucousal lining, see Figure 1. The conchae guide the air aerodynamically, enlarge the internal surface of the nasal cavity and are well supplied with blood to facilitate warming of the passing air. The conchae also guide the air to the olfactory mucosa, which is located in the upper part of the nasal cavity, above the smallest conchae (under the skull base, between the eye sockets).

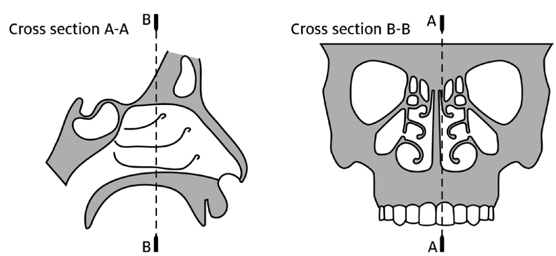


*Figure 1. Left: Cross section of a nasal cavity in the sagittal plane, with three bone plates (conchae) above each other. Right: Cross-section of a nasal cavity in the transverse plane. The six curled structures are the bone plates (three per nasal cavity)*

### *2.2.2 Olfactory sense*

The olfactory mucosa or olfactory epithelium is composed of supporting cells and sensory cells, called olfactory receptor neurons. The distal side of an olfactory cell ends in an olfactory cone, which is covered with hairs or *cilia*. The cilia protrude from the mucosa and are covered with olfactory receptors. Some spurs of different olfactory cells form bundles which are called olfactory nerves or *nervii olfactorii*, which run from the nasal cavity to the olfactory bulb. From here, nerve impulses are

directed to other parts of the olfactory system in the brain and to the rest of the central nervous system, via the olfactory tract.
Air passing the olfactory mucosa can contain odour molecules. These molecules dissolve in the mucosa, which enables them to bind to the olfactory receptors. Which receptor an odour molecule binds to, depends on the chemical, electrical and spatial qualities of the molecule. The receptors convert the interaction with the molecules into a nerve impulse, which is passed on to the bulbus olfactorius via the olfactory cell and a nervus olfatorius.
Humans harbour about 12 million olfactory receptors, divided into 10.000 different classes. Every receptor can be activated only by odourants with a similar molecular structure. Most odour molecules activate more than one type of receptor. Difference in affinity results in various activation patterns, leading to unique flavour profiles. Virtually all fragrances activate not only the olfactory sense, but also the somatosensoric receptors, which detect e.g. temperature, pain, deformation, especially at high concentrations.
Olfactory signals are processed differently from signals of other senses. Usually, when sensory signals enter the brain, they are first filtered by the thalamus. This is a part of the brain that selects which signals proceed to the cortex, where they will be noticed consciously. However, olfactory signals are the only sensory signals that are not filtered, they pass by the thalamus and go straight to the olfactory cortex and are thus always noticed. This allows the brain to react immediately in dangerous situations.
The bulbus olfactorius sends the olfactory nerve stimuli not only to the olfactory cortex, but also to the hippocampus, the hypothalamus and the amygdala. The hippocampus is of importance to memory. The hypothalamus regulates the autonomic nervous system via hormones, in case of e.g. hunger, satiety, aggressive and defensive behaviour and sexual arousal. The amygdala connects information from different senses and correlates it with emotions.
Odours elicit reflexive secretion of saliva and gastric juice at the smell of food and affect the sacral spinal sexual reflexes. Smell therefore plays a role in attraction between people.
Humans have a memory for odours. Certain smells can evoke a strong association with early childhood. Perhaps this has to do with the evolutionary old age of the olfactory sense and the fact that information from the olfactory nerve is not filtered by the thalamus. 'Smell, memory and emotion' is said to be an interesting evolutionary triad [2].

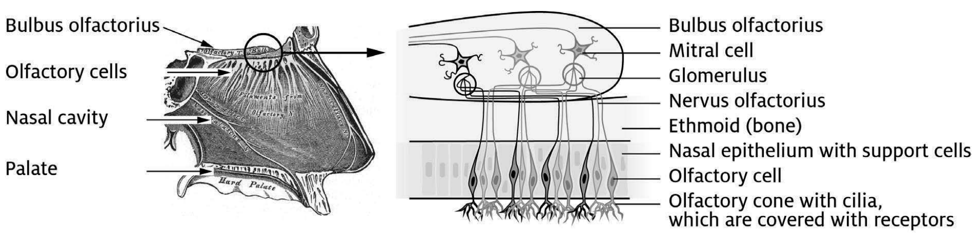


*Figure 2. Left: a crossection of the nasal cavity [3]. Right: a part of the crossection is enlarged, the bulbus olfactorius and the olfactory cells are shown*

### *2.2.3 Sense of taste*

Sense of taste is the ability to perceive certain chemical compounds directly as 'taste'. There are only five types of taste receptors, perceiving the 'primary tastes' sweet, sour, bitter, salty and umami (savoury). These receptors are less sensitive than the olfactory receptors in the nose. The five primary tastes together make up only one part of taste experience. The sense of smell is an important complement, thus many more different substances can be detected. What we call 'taste' in everyday life, is actually a combination of smell and perception. When olfactory sense can not contribute to taste, e.g. in case of a stuffy nose, the taste is largely gone. This clearly 'shows' the importance of smell in taste perception.

### 2.3 Characteristics of smell

Each human has about 10.000 different types of olfactory receptors. The same amount of odours can be detected and a sheer unlimited number of combinations of these odours. With this system, scents can be identified which have never been smelled before. The olfactory sensors are very sensitive and can react to very low concentrations of gaseous substances [2]. The human ability to smell is quite good compared to animals in general. Which substances can be perceived by olfaction, varies greatly between species and also between individuals. The sense of smell is fixed in the genes, every type of olfactory receptor is encoded by a separate gene. Thus sense of smell is hereditary and we have about 10.000 different genes to code for it. Some substances can be smelled by one man, but not by another. This is equally applicable to the sense of taste: not everyone has the same taste perception. Stevia (sweetener) is experienced as bitter by some [4], [5].

Odours can be detected at a distance. Because the concentration can also be perceived, the direction of the source can be determined. The sense of smell can not be manipulated or disabled by external factors [6]. The brain, however, can influence the experience of odours. A foul odour serves to warn for spoiled food and to stay away from stools of others. This reduces the risk of infection. However, it is not useful when a smelly diaper evokes disgust in a parent. Mothers find the dirty diapers of their own babies less smelly than those of others [7].

#### *2.3.1 Effect of aging and disease on olfactory ability*

Sense of smell and taste both decline with aging [8]. Olfactory sense can also decline because of brain damage, infections, mental illness, smoking and hormonal changes. Taste can also decline because of consumption of drugs such as caffeine [9]. People who can not smell (sufficiently) are disabled. It is dangerous not to be able to smell gas, fire or foul food and it is impractical not to be able to judge if you clothes should be changed. As there is currently no word for smell disability, it is proposed to name it '*reuf*', which is a contraction for the Dutch words 'reuk' (smell) and 'doof' (deaf) [10].

## 3 DESIGN FOR OLFACTION

Technical development allows nowadays for many ways to incorporate smell in products. Odour may be added to plastics and printing ink, enabling amongst others *scratch 'n sniff*. Design for olfaction can have various goals, for example to prevent, mask, disperse or control odours, to attain a congruent smell, to transfer information or warn, to influence the environment, to influence the emotions of users or other people, to prevent allergies or to design for babies. These topics are discussed below.

### 3.1 Prevention and masking of odours

In modern life, a lot of attention is given to avoiding and masking scents that are considered unpleasant. Soaps, cosmetics, detergents, washing powder and other cleaning products are almost only available with added perfumes. Medication, food and clothing may contain fragrances, too. Pine scent refreshes toilets not only at home but also in most public places. Ubiquity of fragrances is very unpleasant for people who are allergic to them and it can increase the number of allergic people, too. This is reason for caution. Body odour and other natural odours have a function, so one may wonder whether it is wise to replace them with allergenic synthetic fragrances.

### 3.2 Dispersion and control of odours

Some products are specially designed to reduce odours (other than that of the product itself), or to distribute them properly. Odours can be restricted by sealing (like a refrigerator box), by adjusting the air flow (ventilation, extraction), by absorption (smell-busters in shoes) or by applying odour repellents (like sportswear with silver compounds that kill odour-producing bacteria).

Fragrance is better dispersed when the contact area with the air increases, when heated or evaporated and by ventilation. A larger contact area can be obtained by e.g. spraying. Products to spread fragrance include lavender sachets, fragrance balls, perfume atomizers, incense oil burners and air fresheners for the bathroom.

### 3.3 Congruence

Each material has its own scent. If the scent of a product does not match the expectation of the user, they are incongruent and feel like a mismatch. This also applies to taste. If you think you take a sip of wine but it is actually grape juice, you are unpleasantly surprised. In an industrial product, the smell may differ from expectation by material treatments and additives such as glue, paint or preservatives.

Disturbing incongruity may best be avoided. However, most associations with odours are acquired. By the current 'odorizing' of western society, incongruent odours are becoming more implemented and accepted. Sometimes this leads to strange conditioning or misunderstandings.
"Yuck, this pudding smells and tastes like toilet cleaner" (teenager, on lime-pineapple-coconut pudding).
"I thought I bought a nice cake with apple and cinnamon. Smells like it, anyway. But it's something else. I don't know what, but it's no apple pie. Can you see what it is?" (Woman, 77 years, on a scented candle).
Although incongruent smells are generally not advised, they may be used to obtain a certain effect.

### 3.4 Information and warning

Scent is not often used provide information. Scent is an excellent warning sign, though, because by nature people are already alarmed by the smell of fire and they will not consume foul smelling food. To odourless gas, for example, a fragrance is added in order that a gas leak can be rapidly detected. In Germany, a bicycle helmet is developed incorporating micro-capsules which give off a smell if the helmet is damaged, even when the damage is undetectable by eye. Such a warning method is suitable for all products where material failure is difficult to observe, such as helmets, pressure pipes in washing machines and other constructions which are difficult to access. Scent sensory material can also be applied to detect cracks in water and gas pipes, because the fragrance can be smelled from a large distance.

### 3.5 Influence on the environment

Odour can have a specific function with reference to the environment. For example an insect repellent or moth balls. The smell is functional for the users: they know that the agent is present and working.

### 3.6 Influence on emotions of users

Because the olfactory sense, as mentioned, affects the subconscious and emotions more than the other senses, fragrance seems an attractive medium to influence the emotions of consumers or users. In marketing, fragrance is used to get people in a positive shopping mood. In doing so, the smell must fit the environment well (be congruent). Coffee scent will likely boost sales more in a food store than in a jewellery store. There are two problems here: firstly, the relation between odour and emotion is to a large extent determined individually. A pleasant perfume to one customer may not appeal others. So a specific fragrance does not evoke one and the same emotion in a group of people. It is not possible to predict or have control over the evoked emotions. Secondly, the widespread use of fragrances, especially in public places and in hygiene products, is unhealthy for people who are allergic to them.

### 3.7 Allergy prevention

The ubiquity of fragrances is a serious health problem for people who are allergic or hypersensitive to certain fragrances which can be up to 9,7 % of the general public for a mix of fragrances [11]. They may experience, amongst others, itching, eczema, concentration problems, asthma, a runny nose and burning eyes. Fragrances are even a major source of contact allergy. About 16 % of European eczema sufferers are allergic to fragrances [12], [13]. Frequent exposure to allergens can trigger allergies. Buckley et al. [14] investigated allergy to fragrances and found that older people are more often allergic. They assume that fragrance allergy is caused by a continuation of repeated exposure to fragrances and age-related factors. An allergy to fragrances is usually permanent. It is therefore wise to be careful and apply fragrances with restraint. In public spaces and in other situations and products which users can not avoid, fragrances are advised against.

### 3.8 Design for babies

Adults can differentiate other people by their odour, when we are open to it and stand sufficiently close with our nose. For newborn babies, the olfactory sense is paramount, because their sight and hearing is not fully developed and therefore not yet operational. Thus, babies recognize their parents by their body odour. How to design baby products according to this knowledge? Close your eyes and go around sniffing the baby room with their perception in mind. Newborn babies do not care about flowers, washing powder fragrance or fresh paint. They love the smell of breast milk and their parents sweat and body odours. Is recognition of the parents not obstructed by the use of fragranced washing powder? Perfume less washing powder may be preferred, which has another advantage: you can smell if the laundry is sufficiently clean.

## 4 DISCUSSION

In industrial design engineering, olfactory design is not a main field of interest and smell is generally given little thought. Nevertheless, for many products, more attention to olfactory factors can benefit the quality of the entire design and the health of a significant part of the population. Until now, there is no standard method available on design of industrial products for olfaction.

Education presents a good opportunity to advance in this relatively new field. Students can be requested to give attention to this subject by including olfaction in the design brief. Students have more opportunity than professional designers to explore the field freely, they are not limited by client requirements. They have to substantiate their design choices and have to defend these to their supervisors. If students give olfactory design sufficient consideration, they may advance the field by contributing to the development of a body of knowledge and a method to design for olfaction. After graduation, they can use this to advantage in their professional work, simultaneously disseminating their knowledge.

## 5 CONCLUSION

Designers should spend conscious thought on olfactory factors in a product. A product should smell congruent to its material, function and context, unless the designer deliberately intends the smell to be incongruent. Odour can be a powerful instrument to influence emotion and reflexive reactions, but it is difficult to put this use into practice. Odour can be used very effectively to give warning in some situations. Attention must be given to fragrance allergy, which affects up to 9,7 % of the population. This percentage is rising, allegedly because of increasing application of fragrances. Application of fragrances in public areas and in situations and products which users can not avoid, is advised against. Education presents a good opportunity to advance in this relatively new aspect of design.

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# REASSESSMENT OF THE CRAFTED MEANS OF PRODUCTION IN INDUSTRIAL DESIGN

**Jorge Andres CARO DEL CASTILLO HERNANDEZ and Arild BERG**
Oslo and Akershus University College of Applied Sciences

**ABSTRACT**
This paper discusses the ways in which a reassessment of the crafted means of production could help provide the workers in the production segments of the design industry with improved conditions and greater credit for their work. With this, it is planned that crafted products would be more open and accessible for the general public. Results from the literature review were compared with the opinions and ideas of experts in the field. The results revealed that the desire to improve the conditions of production workers is, and has been an essential theme in the industry. However, the conditions of the production workforce have remained unchanged due to the existing production system. To generate a sense of value in the production labour force it is necessary to reassess the production system. Ideas related to crafted and local production can facilitate this change.

*Keywords: Ethics, craftsmanship, labour force, production processes, industrial arts*

## 1 INTRODUCTION: ETHICS IN DESIGN
Designers seek one simple purpose: to make people's lives better. Ethical research on the design process [1] has shown that designers are preoccupied with pleasing the client or user by making products that can make a positive impact on their lives. Some designers work for the sake of making the world a more beautiful and easier place to live in, thereby spreading joy and pleasure. Because designers are called to please the user, solve problems, generate solutions, and improve methods through criticism, there is a tendency among them to overlook the stages and workers involved in the design process, including production.

### 1.1 A tangible reality of the production process
When a consumer obtains a piece of furniture, for example, they often appreciate the designer who projected it, the firm that developed and sold it and the qualities and origin of the materials. This paper will focus on the often-overlooked people in the early production stage of the design process that work with their hands to make a tangible reality of what initially only exists in the minds of the designers. These individuals are referred to as workers, operators, craftspeople, artisans and members of the labour force [2]. These labels can depend on the type of work they do and their level of status. The design and manufacturing industry must reassess the system so these workers who don't receive the appreciation and encouragement they deserve, could finally achieved. It is important to mention that some craftsmen and artisans in wealthy and developed countries have indeed achieved good standards, markets and fair working and living circumstances, this group represents the model on how the conditions should be, and because of that, this paper would not be dedicated to them. It is also important to state that this paper does not refer only on craftsmen of developing countries. It is true that most of the workforce in the design process comes from developing countries (such as BRIC), but since the developed countries are the demanders, it is a shared responsibility that concerns both the consumers and the producers. With this I mean that industrialised countries should demand more local production made by crafted ways, this way these means of production would become more common, therefore more accessible and less luxurious. Also the developing countries that work as "factories" should increase the value and relevance of their crafted production in order to make more artisans and fewer workers. Society needs good quality and standards as much as good designs, but even more so, society must be willing to work toward achieving fair circumstances for all the people involved in the production and design process. More than 100 years ago, William Morris said it aptly: 'An art made by the people and for the people, [is] a joy to the maker and the user.'

## 2 METHODS: LITERATURE STUDIES AND INTERVIEWS

This present study developed in several stages and combined literature surveys with qualitative interviews [3].

### 2.1 Literature: ideologies on design production

The literature review was conducted to establish a solid methodology for the development of the interview format. The first stage of the literature survey included an analysis of key topics concerning the ideologies and methods of the founders of the Arts and Crafts Movement. Books including *The Stones of Venice* [4]*, Hopes and Fears for Arts* [5] and *Signs of Change* [6] were included to examine the importance of hand craftsmanship and its relationship to dignifying the labour force. These books discuss political and social ideologies, which led to the analysis of additional texts to examine the connection between the socialist currents of the era and the working class. This analysis included *Fields, Factories and Workshops* by Peter Kropotkin [7]. To evaluate the perspectives of modern thinkers, the literature survey incorporated texts written by the authors Peter Stansky [2], Gillian Naylor [8] and Helen Dore [9]. These authors' works provided excellent information on modern theories and tendencies in the field of ethics and production methods [1,10]. Likewise, the review included works discussing the living conditions among people in some segments of the production workforce. Works by Peter Fry [11], Hans Weiss and Klaus Werner were consulted. Researchers also made a comparison of the theories and information gathered from both currents through a qualitative analysis of pattern matching, which identified similarities and differences [12,13]. This literature review provided the foundation for the development of an interview format with a common pathway.

### 2.2 Qualitative interviews of two experts in the field

The second stage in this present work was qualitative interviews at a product design education in Norway. Informants were selected based on the assumption that the segment of knowledge examined in this study is not highly relatable to the public. Individual interviews with professionals and experts in the field were performed rather than large surveys to provide a more relatable structure [3]. A professor and a technician in product design education at the bachelors and masters levels were interviewed to obtain qualitative data on relevant issues and topics related to the research question.

### 2.3 Qualitative analysis

The third stage included a qualitative analysis of the data to compare similarities and differences [12] between the literature and the interviews. It was sometimes a challenge to compare the literature and the empirical data [3]. The analysis was based on grounded theory methodology [14] in that relevant data was collected first to allow a conception of the research question. Because this paper is based primarily in literature, this method was useful to identify the essential topics from the various sources.

## 3 CRAFTSMANSHIP IN PRODUCTION

A large body of evidence exists on the research topic. More than a century ago, individuals such as Augustus Pugin, John Ruskin [15], William Morris [5], Arthur Heygate Mackmurdo, Peter Kropotkin [7] and, more recently, Gillian Naylor [8], Peter Stansky [2] and Tony Fry [11] attempted to draw attention to the importance of the human resource within the central topic of craftsmanship in the production and industrial processes. These researches tried to increase awareness in society regarding the bad conditions of the working class through examples and facts. The concepts in works such as *Hopes and Fears for Art* and *Signs of Change* by William Morris [5], *The Seven Lamps of Architecture* and *The Stones of Venice* by John Ruskin [4] and *Redesigning the World* by Peter Stansky [2] will be discussed in this paper, as they form the cornerstone for this theoretical research.

### 3.1 The revival of craftsmanship

Two categorical theories were identified in the literature. The first category, represented by workers and craftspeople, explored the thoughts and concerns of people closely related to design, industry, production, labour and the workforce at the end of the 19$^{th}$ Century. At this time, John Ruskin [4], William Morris [2] and Arthur Mackmurdo insisted that better circumstances for the people could only be achieved through a revival in craftsmanship. Those theories can expand the understanding of the situation in the workforce today.

The second category of relevant literature consisted of reflections about the current situation and circumstances production workers industry and design live in today [11]. This literature also discussed recent research on the problems of ethical conditions for the workforce and the perception of human resources [1]. These works debate new theories on how to improve the modern circumstances in the production segments to generate better conditions in sustainability, human rights, ethics in industry and fair trade [10].

### 3.2 The intrinsic relationship between the worker, the object and the public

To learn how these two different categories of literature, which represent different approaches and subjects, might complement each other, this study first examines the categories of theories individually to find information on methods. Morris and Ruskin were aware of the state of the production workforce in the late 19th Century. They claimed that the capitalist system was making production competitive instead of cooperative, which was driving the workforce and quality of production into a struggle to maintain fair conditions [4,6]. Both writers claimed that the quality of life of these workers was gradually worsening and would continue to do so unless there was recognition of equal importance in the intrinsic relationship between the worker, the object and the public [2].

The researchers asserted that better conditions for the workforce would lead to a more homogeneous society with fewer divisions and economic differences, but also with similar tasks, responsibilities, rights and obligations. Ruskin said, ‘In each several profession, no master should be too proud to do its hardest work. The painter should grind his own colours; the architect work in the mason’s yard with his men; the master-manufacturer be himself a more skilful operative than anyone in his mills’ [4]. Morris claimed,

> Now as I am quite sure that no art, not even the feeblest, rudest or least intelligent, can come of such work, so also I am sure that such work makes the workman less than a man and degrades him grievously and unjustly, and that nothing can compensate him or us for such degradation: and I want you specially to note that this was instinctively felt in the very earliest days of what are called the industrial arts. [5]

There was a generalised concern for workers among many groups in the late 19th Century, which was influenced by the emerging socialist philosophies. Many designers, including Morris, were attempting to merge the socialist doctrine with the design and production industries [2]. Considering this, two topics were held up as especially relevant. The first of these was the position of the machine in the workforce, and the second was the system of competition in which the means of production were founded.

These authors were not against industrialisation or automation of the production duties of workers; ‘…life without industry is guilt, industry without art is brutality’ [15]. They believed the essential purpose of the machine was to make the work of the people easier and more bearable, rid the industry of dull and repetitive toils and give workers a chance to apply their time and efforts to more fulfilling activities. Morris reflected on this idea when he established the separation between Mechanical Toil, Intelligent Work and Imaginative Work [5]. He suggested that mechanical toil was the enemy of the worker, and imaginative work was the desirable end wherein the worker was able to enjoy the duties and provide better results. Nevertheless, despite these ideals, the machine has brought more and harder work to the people in many cases. The automation of tasks and the reduction of labour within those tasks have made work simpler. However, this has resulted, not in less work overall, but in more work in the same number of hours. Machine automation, then, has mainly served those seeking bigger profits. Morris and Ruskin argued against the people who used machines to get profit rather than to provide fair conditions for workers: ‘But why is he the slave of machinery? Because he is the slave to the system for whose existence the invention of machinery was necessary’ [6].

The second great concern in the industry of the 19th Century was the mind-set where production of goods was viewed as a war rather than a supply of needs. This system of consumerism and mass production created a deep chasm between the labour force and the ‘owners’ of that labour force, (i.e., the owners of the means of production upon which the unprivileged classes were forced to rely) [6]. During that period, the differences between the labour force and those above it was seen almost as a kind of slavery: ‘Our society includes a great mass of slaves, who must be fed, clothed, housed and amused as slaves, and that their daily necessity compels them to make the slave-wares whose use is the perpetuation of their slavery’ [6]. Though it was a drastic affirmation, the analogy to slavery increased awareness of the endless circle of poverty within which the production workforce was living. It also drew attention to the hopelessness of the situation in the absence of reform. Thus, a call was made to the society to treat each one of its members with the same dignity, ‘No man would be tormented for the benefit of another—nay, no one man would be tormented for the benefit of Society. Nor, indeed, can that order be called Society which is not upheld for the benefit of every one of its members’ [6].

The industrial revolution brought about significant changes in the social and economic structures of society and settled the foundations for what today is the ruling production model. The need today is to examine the situation and learn what can be done to understand and improve these modern models of practice that designers encounter.

Studies on the smaller or larger scale of mainstream production today reveal that the abyss between the labour force and the owners of the production companies still exists today. The situation has not improved since the late 1800s. Today, large segments of society, including whole communities, cities and even entire countries represent the labour force. Likewise, the face of the modern-day owner has evolved. However, it is not the intention of this paper to enlist or give drastic examples of the bad conditions in which some segments of society exist, so this relevant topic will not be addressed in the current work.

### 3.3 A systemic view

Not only has the gap between workers and owners increased but it has also extended to new places; whole communities, societies and cultures now support the system of competition, while the segment that benefits is much smaller than the segment supporting it. Author Tony Fry explains that people have become too dependent on the artificial worlds they have designed, fabricated and occupied [11], and in order to improve, society must get rid of the idea of ‘thinking in the moment’. His basic premise is that people should have greater power to choose the forms of the environments in which they live. That this way of life should enhance the environment in general is the common thread. However, history has demonstrated that the realisation of this idea is often problematic [11].

### 3.4 A content client and a content worker

To illustrate the central theme of this current research, it is important to discuss how these two approaches are relevant. The theories proposed by Morris, Ruskin and other authors from the turn of the century were the foundations of the Arts and Crafts Movement. These approaches predicted the future conditions of the labour segment and should be re-enlisted to avoid bad working conditions in the future. These theories are not obsolete, but certainly worth pondering today. If society can merge these two approaches—the importance of craftsmanship proposed in the past and modern theories on ethical conditions for workers—researchers can explore the relevant issues that emerge. It would not be practical or effective to take the late 19$^{th}$ Century thinking and forcefully apply it to today’s very different circumstances. However, these thinkers proposed important elements that, if adapted to today’s perspective with its new theories and practices, could empower disfavoured classes. It is the duty of designers and consumers to consider the workers involved in the design and production processes, because a content worker will create a content client and vice-versa. As it was in the time of Morris, today design naturally connects art and trade and provides a way for artists to make a living and for governments and manufacturers to support artistically valuable causes without losing their reputation for practicality [2].

## 4 INTERVIEWS

The literature studies demonstrated that people have made extensive efforts in many periods to create better circumstances for workers, but that there has been consistent failure to provide fair conditions in the production and distribution industries. These ideologies emerged with the industrial revolution and took the place of craftsmanship. Recent studies have revealed that the same situation is maintained today. Why these unfortunate circumstances have prevailed for more than 100 years, yet no one has been able to establish change, is an important question. The interviews in this present research were designed to expand knowledge in this area.

### 4.1 Fair trade: a fashion or an ethical imperative?

One of the professionals interviewed commented that ‘people do not really care about other people’s condition; the need of cheap and ‘good quality’ production is more important than the fair treatment of the labour force, and it is because of the big importance we put in costs, that then we have to give less importance to other subjects.' He continued: 'People design in mass production because they want to achieve the bigger profit.' This respondent also pointed out that hand craftsmanship has become extremely expensive, and the segment of society that can afford these goods has been greatly reduced. Craftsmanship, then, has become a luxury instead of an activity of the people and for the people. He also said that the only way to give the workforce 'importance' was to incentivise fair trade. However, the interviewee noted that there is a risk that fair trade might not provide a better standard of living. Even the mere idea of fair trade could be difficult to instil in the consumer's mind, because people often see these kinds of ideas as 'labels' and 'fashion'. The respondent went on to say that, like every fashion, '. . . what seems to be relevant today might not be tomorrow.'

### 4.2 Potential niche markets

The second expert interviewee offered a more positive perspective. She affirmed that initiating changed is a shared responsibility between the suppliers, including fabricants, companies, designers, workers and the market on one hand, and the common people, such as buyers and customers, on the other hand. These entities should all take part in providing and demanding crafted products: 'Many things ought to be done at the same time: educating people on a general level, as well as producers, marketing people, politicians and other stakeholders.' She suggested that the modern climate was well placed for this kind of change because more and more people are coming to appreciate crafted production. She went on to say that, 'It might grow into a more substantial niche market—or several different niche markets—as well as an expanded export. Our era of experience economy fits well with a better future for this kind of furniture.'

## 5 DISCUSSION

Opinions on the subject of improvement in production workforce conditions were divided. All respondents and researchers acknowledged the need for change. However, one respondent suggested that, since there has been no change in the past 100 years, change would not come easily today. However, if society begins addressing these matters, people might grow more conscious of the problem and eventually begin taking a stand. A consistent positive mind set in regard to ethical change was evident in the literature [1,1011] and in the minds of the interviewed experts. This research revealed that there is an awareness that conditions are not good, which was also the case in the late 19$^{th}$ Century. The problem is that this knowledge has not been enough to inspire a change. This present study also showed that there is an overall acceptance of the current system because it benefits a segment of society; though this segment is not the largest it is the most powerful. It is worth mentioning that the literature and the qualitative interviews produced different data. To some extent, the literature offered more 'romantic' solutions, but the brutal reality keeps these solutions from flourishing.

### 5.1 Conclusion: corporate social responsibility

It is the responsibility of designers to consider themselves and the clients, but also the workers in the segments of production outside their own practice. This could set in motion the establishment of a system designed to make products and production and design processes friendlier for the people who fabricate the goods. If designers equally reflect on the people in the production stage and the income generated for the owners, the beginnings of change could emerge. This change in mind set could also contribute to corporate social responsibility (CSR) where businesses are positively branded in the market [10]. A person involved with design can choose to take a stand in this matter of ethical values to contribute to making design a noble discipline [1,11].

'Is that, indeed, too extravagant a hope? Have you not heard how it has gone with many a cause before now? First few heed it; next most men condemn it; lastly, all men accept it – and the cause is won' [5].

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# PROMOTING ENVIRONMENTAL SUSTAINABILITY BY FOSTERING A CULTURE OF MATERIAL ETHICS

**Shannon CHANCE**[1] **and Pearl O'ROURKE**[2]
[1]Hampton University; The College of William and Mary; Dublin Institute of Technology
[2]Dublin Institute of Technology

**ABSTRACT**
Creating a culture of 'material ethics' can help engineers and product designers in the quest to achieve environmental sustainability. By framing this particular issue and focusing attention on it, Engineering and Product Design educators can help establish a shared language to undergird students' conceptualizations of the natural world and instil a healthy sense of interdependency and responsibility. Overall, this paper explores the idea of 'material ethics' and presents arguments and applications for building such a culture at the tertiary level. As design educators, the authors of this paper aim to provide a broad and useful overview of environmental issues relevant to Engineering and Product Design Education (EPDE). They examine the role of the university in general and of EPDE programmes in particular in working toward environmental sustainability. They identify ways to integrate environmental topics into university activities and curricula, and they cite a variety of sources to back their arguments. They note that, today, digital environments inform many students' perceptions as strongly as physical environments. Students' understandings of the natural environment are now weak due to factors that include digital immersion. In response, the authors urge educators to prompt students' exploration of issues of environment and materiality. They provide examples to serve as points of reference and inspiration. By helping students recognize moral imperatives, such as achieving environmental sustainability, and helping them assess and implement 'best practices' into their design processes, teachers can help shift the prevailing paradigm and prepare students to tackle society's most pressing environmental issues.

*Keywords: Materials, Resources, Ethics, Values, Design*

## 1 INTRODUCTION

> *Design responsibility means that designers always should be conscious of the fact that, each time they engage themselves in a design project, they somehow recreate the world.* [1]

The 'ethics of materiality' is also referred to as 'material ethics'. It encompasses the way societies behave with regard to the things they make, how they manage resources, and how their attitudes change over time. It provides a helpful framework for helping address current deficits in Engineering and Product Design Education (EPDE). In general, scholars of material ethics consider how groups of people deal with material culture, and more specifically, how they value and construct objects and how they speak and teach about the material world [2].

In this day and age, students use diverse technologies, virtual simulation, and digital fabrication. As a result, getting them to understand, interact with, and respect physical materials has become more challenging. By pulling the issue of material culture into focus, educators can help their students and their professions in establishing a healthy, shared sense of the natural world. This can help students and society achieve a more effective balance between human activity and natural context.

Warwick Fox [3] has argued: "we simply have one big problem in regard to the ethics of the human-constructed environment, namely, the fact that there presently isn't one!" (p 122). An Emeritus Professor of Philosophy and a bio-ethicist, Fox has identified the three specific realms of ethics. As illustrated in Figure 1, Fox labelled these realms as: (1) bio-physical, (2) symbolic, and (3) material. Biophysical ethics relate to ecosystems, as well as the animals and plants that live within them. The symbolic realm of ethics, Fox says, grows out of the moral agents embedded in human language. Material ethics has to do with "all the 'stuff' that humans intentionally make". Although most cultural groups have developed coherent values that relate to symbolic and bio-physical aspects of life, the same cannot be said for aspects related to materiality. The ethics behind what (and how) we *make* remains ill considered today - despite the fact that material ethics has historically been a central topic of architectural philosophy [4] as well as architectural and industrial design (see the Bauhaus movement). “We clearly need an ethics that can directly address concerns at the relatively intangible level of design,” says Fox. To fill the void, he suggests that humans work to develop a more effective code of ethics regarding the material world. Those who enjoy the highest levels of material wealth have the greatest obligation to develop effective responses; however, they are often the most oblivious to the impact of their decisions. They also tend to generate the most waste and to consume materials at the highest rates.

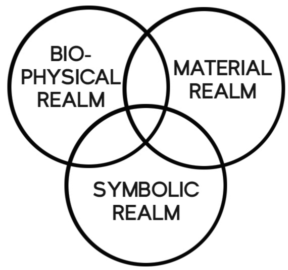


*Figure 1. Venn Diagram of Fox’s Framework*

Matt Ridley [5] claims society has prospered as a result of its ability to accumulate collective intelligence. Ridley references common products—such as the computer mouse—to illustrate how today’s processes for mass-production are not using adequate life-cycle perspectives. He explains that we live in a globalised world of isolated industrial silos that integrate with one another in limited ways. With regard to the computer mouse, the people who extract the oil to make a computer mouse have different knowledge and skills than those who produce the plastic, transport the materials and components, design the hardware and software, develop the tooling, manufacture the product, assemble it, deliver it, and ultimately sell the product. These different players often have little awareness of where the components they use originated and little understanding of the complex web of relationships of energy and elements used to create the object.

Every choice a designer makes can have huge social and environmental affects throughout the process of producing, using, and disposing of the product. Society has now reached a point of crisis, and the educational system is largely to blame. Reynolds, Brondizio, and Robinson [6, p xiv] assert:

> *the American educational system has been turning out ‘environmental illiterates,’ ill-equipped to understand emerging information about the environmental, social and economic dimensions of human-environmental interactions and make informed choices on the suite of issues, from lifestyle to politics, that will decide whether and how society moves toward a more sustainable economy.*

Exacerbating this problem, most curricula on university campuses short-sightedly “condition students to view the natural world as a collection of objects that can be manipulated through science, technology, and human economic interests” [7, p193] rather than part of an interdependent system. Most engineering, product design, and architecture curricula impart such values today, in implicit and explicit ways. As design educators, we can start by addressing this problem head-on. We can instil more effective values and behaviours in our students, with regard to materials, their value, and their use.

## 2 ROLE OF THE UNIVERSITY

We believe that to achieve environmental sustainability, all institutional planning, action, and decision-making should be informed by a coherent set of ethics—one that includes the environment to a much greater degree than has been the case since the Industrial Revolution. The overall role of the university is to generate knowledge at the level of the individual and to help address the most pressing issues facing society. To do this, universities are charged to create and test new solutions to emerging and/or newly identified problems [8]. A core purpose of the university is to produce citizens who can contribute to society in big and small ways [9] and it is hoped that third-level institutions provide students and faculty “cultural and intellectual space where critical reason may develop” [10, p4]. Today, many universities are implementing environmentally sustainable practices and working to foster engagement, participation, and collaboration from their constituents [11]. Study of the environment, which was once confined to the pure and nature sciences, is now being seen as a central issue that requires input from many fields. Institutions that adopt comprehensive approaches to design curricula understand that bridging liberal arts with technical sciences enriches coursework overall [2]. Course work, as well as the buildings and environments that courses are taught in, can help convey information and change behaviour [12]. Buildings themselves "ought to demystify the world, making us mindful of energy, food, materials, water, and waste flows" insists David Orr [2, p220]. Working at Oberlin College, Orr and his students helped set a new standard for the design of buildings. They sought to embed values into their new study centre for environmental studies. This building has served as a precedent for LEED Green Building Rating system and for hundreds of subsequent built artefacts that have been designed to serve as tools for teaching and learning about the environment.

## 3 THE UNDERLYING PARADIGM

Third-level educators can begin to raise questions of materiality in projects in formal, as well as informal, learning environments around campus. In doing so, we can inspire our students to confront difficult challenges. We can help transform "the way our students interact with the world and one another" [13, p5]. According to this constructivist paradigm, teachers and researchers serve as collaborative participants who engage with their students in the iterative and on-going process of identifying crucial problems and defining possible solutions. In this way, educators can prompt students to become "active generators of new knowledge" and help students become "participants in new problem-solving networks" [14, p147]. "Each of us has a part to play" in efforts to change human behaviour and achieve environmental sustainability [15, p22]. The curricula we offer can weave together issues of values, ethics, and human-environment relationships to help students gain a healthy sense of interdependence [16].

## 4 ROLE OF DESIGN PROGRAMMES

Design programmes prepare students to shape the physical world. They help their students understand where materials come from, what properties they have, and how they can be used to create structures and artefacts. As design educators, we can help students learn to value, experience and express "materiality". We can encourage students to track material flows and consider the transformation of materials over time as they pass through the production cycle.

Ethical design is an ideology that can be fostered rather than a tool or skill that can be taught. It requires the designer or student to sense a duty of care, which surpasses the notion of designing products that are simply safe to use. Under the emerging paradigm, products can be holistically considerate of society, culture, *and* the natural environment. Environmental issues can be integrated into design projects and well as specialized technology-focused courses. "Unless sustainability engages with the [design] culture, it fails to address the process and philosophy of design education" [17, p136]. It cannot be confined to seminars and other support courses if it is to affect the way designers think and act. In support of this idea, the American Institute of Architects [18] now recommends that design schools take a holistic approach, integrating issues of social justice with ecological sustainability [19].

Hands-on, experiential design pedagogies, like those used to teach architecture and product design, are very effective in imparting such values. Education researchers have found that hands-on problem solving and active inquiry-based learning facilitate high-quality learning [16, 20]. These practices help students learn more deeply and retain what they have learned longer than traditional delivery formats. Still, design educators and students can set a positive example and do more to promote material ethics across campus. By carefully considering Fox's [3] claims as discussed, we can become more intentional in our actions. We can speak and act in ways that addresses society's lack of material ethics. In doing so, we can come to serve as examples for other professors and programmes on campus—challenging more and more educators to address Fox's ethical challenge.

*Teaching designers about materiality*

Researching applied topics elicits strong involvement and productive learning among students Hopkinson, James, and van Winsum say, citing transportation, energy, water management, and waste handling as research topics that spark enthusiastic engagement [21]. Students "learn a great deal not only about the technicalities of the topic, but also about how what happens in practice is influenced by organizational and personal factors" [21, p91]. A holistic approach to the teaching and learning of material ethics facilitates "an integrated effort," towards ethical design, rather than "a piecemeal activity involving tacked-on concepts and technologies" [22, p78]. Designing with respect to nature as well as people and economic forces requires making choices about everything from energy to agriculture and land use, from settlement patterns and methods for distributing water and handling waste to the use of materials and other resources [2].

*Assignments Stimulus*

With regard to product design, useful topics to consider after evaluating the social implications of the functionality of the product include: DFE (design for the environment), LCA (life cycle analysis), adaptive mass customization, modular product design, and design for disassembly. An example assignment in this realm involves storyboarding. The educator can ask students to storyboard a product's life cycle while considering: material extraction, material production, manufacturing and assembly, product use, transportation, and end-of-life disposal (see Figure 2).

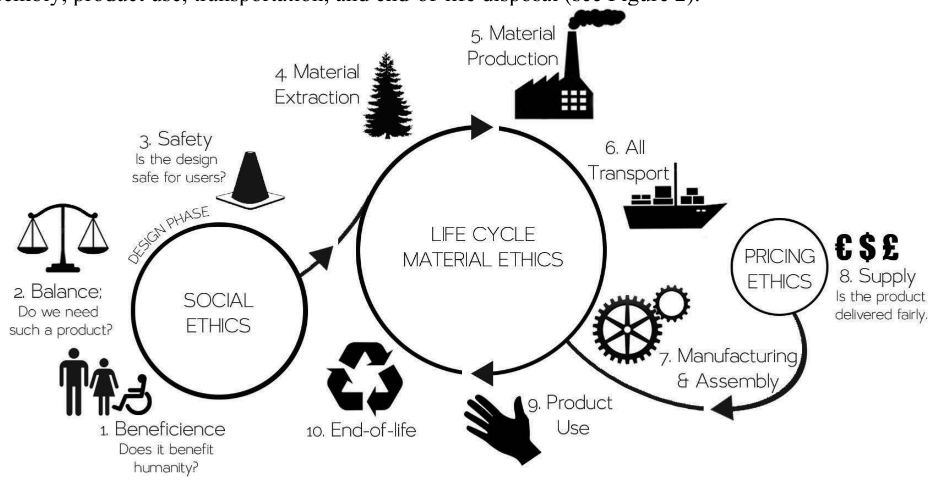


*Figure 2. Design Ethics Landscape*

Although the resulting storyboards may be relatively superficial when undertaken by undergraduate design students, they can serve as a useful stimulus for group dialogue and may highlight students' responsibilities as designers.

Another way educators can encourage consideration of material ethics is by discussing the notion of dematerialization (i.e. how tangible products can be replaced with services or systems). Examples include timeshare systems, products of service [23], and virtual libraries and archives. Service, software, and system conceptualization requires the same creative integrative skills as traditional product design, but the end result is different—and not necessarily a material artefact. For more ideas on teaching sustainable engineering and product design ethically, see Papakek's seminal texts [24, 25].

## 5 BARRIERS TO MATERIALLY-ETHICAL DESIGN

Identifying and understanding existing barriers is crucial to overcoming them. We characterize some of these barriers as: the perceived dichotomy that places production and economic viability at odds with ethics, lack of clear definitions and standards regarding ethics and green design, and differences between mass production and the prototyping that leads up to it.

*The dichotomy between material ethics and production strategy*

Design education fosters the practice of perceiving the world through various lenses and integrating those perceptions. The domains of enterprise, aesthetics/UX, and construction/manufacturing each have their own criteria for success. A contemporary designer's ability relies in part on how s/he works at the interface between domains in the process of creating viable, elegant solutions. Assessing the economic feasibility of a design concept is integral to the design's overall success. Post recession, at a time where profit and employment are important metrics for success, the long-term wins associated with material ethics are sometimes less revered. A Finnish study [26] about product purchasing highlights why public interest in material ethics is low. It found that consumers lack knowledge about how their purchases affect the environment and that they believe the onus is on manufacturers to produce—and distributors to screen for—environmentally sound products. Another inherent problem, rooted in the economic side of product development, involves ‘planned obsolescence’, an idea that has become commonplace and largely accepted across the technology sector. Material ethics is largely concerned with physical obsolescence, which includes products that are designed to fail, are designed for single-use or to be non-repairable, or are designed to aesthetically degrade and become ugly over time [27].

*The fuzzy nature of material ethics*

The concept of ‘green’, ‘eco’, or ‘environmentally-friendly’ design is unregulated and does not always take the whole life cycle into account. These terms are ubiquitous in consumer landscape and, in our experience, often constitute the totality of many students’ knowledge when they begin studying. For example, using materials that are *biodegradable, organic, recyclable or natural* does not equate to being materially ethical. For example, a ‘biodegradable’ paper bag may not be more beneficial than a plastic bag because a) it is less likely to be reused, b) it requires a lot more material by weight and, c) if it ends up in the anaerobic environment of a landfill, more greenhouse gases will be released as it decomposes [28]. This is not to say that paper is an unethical material, but that when developing paper products, it is important to design and integrate cues for ethical use and disposal.

*The dichotomy between prototyping and mass production processes*

Technological innovations have changed the product design process over the last thirty years. CAD systems, finite element analysis software and rapid prototyping machinery have made elements of the design process more efficient. However, these technologies have also widened the schism between the designer’s domain and the manufacturing environment. For example, the additive manufacturing technique used in 3-D printing disguises the importance of many traditional design decisions that are associated with material selection, assembly, or tooling on the journey to prototyping. We believe that unless the aim is to manufacture with a 3-D printer, design educators should guide students in designing for the intended materials and constructively critique material-based design decisions from the outset. Industrial design programmes deliver theoretical modules about materials and manufacturing, but there is space in many programmes for more first-hand experience of the manufacturing world as part of the curriculum.

## 6 CONCLUSIONS

Fox and Orr provide important food for thought. Among academic programmes on third level campuses, design programmes are poised to lead change. Because design professors are accustomed to learning about materials—and teaching others to value materials—they represent a valuable human resource. Our review suggests that they need to be part of larger institutional efforts to infuse sustainability and “material ethics” into many different programmes and into university activities in general. Design educators can become increasingly valuable to their communities by focusing more of their attention on the concept of ‘material culture’ and ‘material ethics’. In doing so, design educators can help address an existing hole in the educational systems of the Western world.

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# EMOTION ELICITING IN AFFECTIVE DESIGN

**Yoke-Chin LAI**
VIA University College, Denmark

**ABSTRACT**
A successful product needs the designer's conceptual model congruent with the user's mental model. The fundamental affective design principle also applies to assistive product design. Eliciting effectively the user's mental model has been a big challenge for most novice designers. This paper outlines the concept of an integrated design method that is developed to aid novice designer through the conceptual design stage. Multi-modal stimulation is used in this design method to induce user's emotion, a key element in the user's mental model. Visio-haptic Augmented Reality technology is integrated with 3D digital prototype as emotion stimulus. To form a closed loop reflective model, the emotion response from the user is assessed with an emotion assessment tool. Emotion ontology is established to form the backbone of the emotion assessment tool.

*Keywords: Assistive product, mental model, emotional elicitation, digital prototype, visio-haptic Augmented Reality, multimodal stimulation*

## 1 INTRODUCTION

The changing age-related demographics raise implications for altering the product demand trend in the society. This is due to the potential product consumers who may be functionally limited by age or disability increases at a dramatic rate. Along with the growing size of this user group, the quest for assistive products that are specifically designed to enhance physical, sensory and cognitive abilities of users is escalating. User's image with respect to the fear of stigma is another key success criterion that is usually overlooked. The design methods practiced in assistive product designing shall be reviewed from the user-centred perspective as the departure point.

This paper is to propose an integrated design method aiming at strengthening the learning outcome in the pedagogical dimension of a design course offered to students at the tertiary educational level. The proposed method is anticipated to be beneficial for creating assistive products that could satisfy the actual affective needs of users. This paper briefly reviews the User-Centred Design relevant methods and tools practiced by students in the design course. The designing shortcomings exhibited in the completed student projects are discussed in an attempt to outline problem areas with respect to assistive product design with focusing the actual emotional response of user. Literatures within the relevant areas including affective engineering and emotion elicitation and assessment methods are reviewed intending to portray the importance of affective needs for successful assistive products. This review lays the basis for the integrated design method proposition, which is explained in end of the paper.

## 2 THE DESIGN COURSE SET-UP

PUDM1 is an elective course offered in every spring semester to the 6$^{th}$ and 7$^{th}$ semester Mechanical Engineering students. The main objective of the course is to introduce user-centred design (UCD) practices to the mechanical engineering students who have acquired adequate engineering design skills in their previous semesters. The curriculum framework of the course is organized in two dimensions: 1) the skill and knowledge learned (curriculum content), and 2) the pedagogical approach (how the skill and approach is learned).

Project-based active and cooperative learning are the pedagogical approach used. Active learning is a teaching approach that involves student-student and student-teacher (facilitator) interactions in various forms to convert the learning environment from passive to active. Cooperative learning is a technique that puts students to work in teams under conditions that promote the development of teamwork skills while ensuring individual accountability for the entire assignment. Students are assigned a design project from the beginning of the semester, which lasts for 12 weeks. The design project is divided into five assignments that combine together to form the whole project. The assignments must be completed in a successive order as the outcomes of one assignment will form the development basis for the next assignment. Each assignment is formulated mapping correspondingly to the user-centred design process: problem area defining, user's needs discovery, discovery data analysis, design exploration and prototyping, and prototype evaluation.

## 3 PROJECT EXPLORATION AND THE ESSENTIAL OUTCOMES

The design project assigned to the students was usually open-ended but with a specific theme, for instance "design a product that assists the mobility of the elderly". Defining an explorable problem area based on inspirations gathered from their living surroundings would be the first attempt for the students to explore the design project. Searching the web and design magazines, observing their surroundings followed by brainstorming were the most practiced methods to find inspirations. Group storytelling was also one of the approaches used by some groups to find inspirations. Failure experiences of every group member were shared within the group through storytelling. A scenario was then produced to outline a problem area. To continue the subsequent step in the conceptual design stage, i.e. analyzing user's needs, a wide range of methods were used by the students. Among these methods were interviews, questionnaire surveys, observations, role-play, persona and mood-board. Persona and mood-board were produced as the media to communicate understandings about the targeted user groups, their use-experiences and needs. A design brief that outlined the problem area and design specification was the outcome of the early design stage.

The design exploration stage started from idea generation. Idea generation was practiced following several parallel paths depending on the nature of the defined problem area. As for a project whose aim was to improve an existing product, for instance a grabber or a can-opener, students were guided to carry out a detailed evaluation on the function and usability of, at minimum, one grabber/can-opener available off-the-shelves. Several usability evaluation methods were instructed for this purpose, including Hierarchical Task Analysis (HTA), Task Analysis for Error Identification (TAFEI) and Verbal Protocol Analysis (VPA). Brainstorming or the engineering-design-oriented tool such as Morphological Analysis, were employed to generate ideas. Showing hand sketches of all of the ideas generated were demanded as a teacher-student communication means in order to gather feedback from the teacher. One final idea would be chosen using some idea/concept selection techniques such as Scorecard, Weighted Objectives table, or multi-voting.

The product development process was then carried on to the detailed design stage. Hand sketches of all of the key components of the final idea would be produced. Hand sketches showing the connecting mechanisms of the relevant moving parts (components) would be produced as the key team-centric communication means. As an alternative, digital 3D models would be generated to express the design concept using CAD software packages such as Autodesk Inventor. 3D scanning technology was not a popular alternative to produce digital models although the facility was available. Physical prototype of the whole or partial product that could enable user interface evaluation would be created using low cost and easy access materials such as cardboards, polystyrene sheet, clay, MDF and metal sheets. The last stage in the design project was prototype evaluation, which was peer-evaluated from the usability perspective in a classroom setting. Rapid prototyping technology was noticed seldom employed by the students although the facility was available and easily accessible.

## 4 THE MISSING ELEMENTS

The design practices performed by the students demonstrated critical shortcomings as follow:

1. Prototyping skills needed room for improvement. Creating digital 3D model using CAD software packages was the most preferred technique. This technique however demonstrated shortcoming in performing usability evaluation as user –prototype interaction was found infeasible. Students reported that physical prototype constructing was time consuming. Rapid prototyping technique was rarely chosen though available. The rapid prototyping method was reported costly by the students. The printed 3D model was usually scaled down and this has restricted its feasibility for optimal usability test.
2. Usability evaluation was inadequate. The aforementioned prototyping situations have caused the difficulty in performing effective usability test. Getting real user involved in usability test of the student project was found another challenge. For instance, a scaled model with very limited

testable functions and user-interfaces was impracticable in this respect as real user's differed from trained/experienced experts as in the focus group study.

3. User need was found not satisfactorily met. User needs were found difficult to be interpreted accurately in many of the student projects. The methods used in the user's need analysis stage were found inadequate to derive the user's actual affective needs, which are tacit. For instance, observation was remarked a subjective method that exhibited shortcoming in the user needs collecting and articulating process. The observable needs analysis could be biased by the observer's personal knowledge and experience. The interview method employed by students exhibited also pitfall with respect to unleashing the user's tacit needs. In interview, the users would tell what they want the designer (student) to hear. Under the circumstances that students were novices in the design area, being knowledgeable to ask the right questions would be a critical skill of which that the novices were lack.

## 5 AFFECTIVE NEEDS FOR ASSISTIVE PRODUCTS

According to [19], functionality and usability are not the only success criteria of a product but also the user's self- image. A person's self-image can be enhanced if the product is consistent with how the user perceives him/her-self and what s/he wants to be and what s/he wants to show off to others. This aspect is of particular importance in assistive product design. A product designed with taking self-image into consideration could offer a product's expression that corresponds to a user's dreams, longings, and desires to make the user regard the product as meaningful. Possessing experience of meaningfulness is essential to encourage user adoption because product as such is perceived by user useful to improve his/her quality of life.

A meaningful user experience is use-context dependent and inseparable from emotion [20]. A positive experience will cultivate a positive self-image to the user. User experience, self-image and user's emotion are the key elements in the study area of emotional affects. As reported by many emotional research literature, for instance [19, 7, 8], that emotional affects have the tendency to change cognitive processes [21] and therefore influencing how mental models are formulated, perceived and interpreted. It can change how people interact with one another as well as with products/objects.

Norman [19] suggests that the mental model of designer could differ from the one of user. A conventional design process (more accurately engineering design process) usually starts from a technical specification. In such technical description, the subjective values, such as experience and emotion, are usually not formulated explicitly. However, these values play a crucial role in providing the designer with a deeper insight and understanding of the user's experience of products. In accordance with Koskinen & Battarbee [20] that designer needs to translate user's experience and emotion into physical products. The question arises here is what approach could a designer use to translate effectively a user's experience, emotions, aspirations, goals, rituals, and values into a product that elicits positive emotional responses?

## 6 EMOTION ELICITING AND ASSESSMENT

In light of the significant role of affective needs, a method to capturing and translating them into relevant design attributes is of need.

Affective engineering is an approach used in the recent decades to elicit affective attributes (e.g. emotion, feeling and experience) from customer or potential user so that the affective attributes can be translated into design specification [7]. In the area of Affective Engineering, diverse techniques including self-reporting and physiological monitoring (e.g. measures of cardiovascular, electrodermal) have been explored [7,8,3] in an attempt to in assess user's emotion.

User's emotion is generated through cognition and five senses: sight, auditory, taste, smell, and touch. Pictures or photos are found in many literatures [5,8,12,3] the widely applied method for the user's emotion eliciting purposes. Those photos are usually taken from a wide collection of some existing products related to the targeted design domain. This method was employed by some project groups of the design course PUDM1 as one of the user's needs acquiring tools. The user's emotional response to the pictures was assessed at the time when the pictures were shown to the user using self-reporting tools including Self-Assessment-Manikin, Plutchik Emotion Wheel and Geneva Emotion Wheel. The emotion words in the self-reporting tools were chosen from various sources including design magazines, user interviews and emotion measuring relevant literatures such as [22, 23,24] so that they could sufficiently describe the emotional responses possibly evoked by the shown pictures. The most used positive emotion words were joy, fascination, satisfaction, pride, hope and desire while the most common negative emotion words were boredom, dissatisfaction, shame, fear, disgust. Likert scale was one of the tools applied to interpret the subjective emotional response evaluated through the emotion words into the corresponding numerical values, which vary from for instance 0 (i.e. no affection) to 5 (i.e. high affection). The emotion assessment results were then used to find a generic trend of likeness of the relevant products.

2D picture in general exhibits a limitation: user-product interaction is restricted. The question is if the use of 2D photos could be further strengthened by some other option to access deeper of the user's expression for probing the tacit needs

Based on the experience accumulated from the design projects completed in course PUDM1, to actively engage end-user participation at the earliest design stage aiming for user's emotion acquiring, a human-product interactable prototype is essential to help designer directly observe what a user thinks or feels while the user interacting with the prototype. In view of such limitations as costly and time consuming exhibited in physical prototype construction, an interactable digital prototype could be beneficial. CAD-based digital model restricts human-prototype interactivity as most end users are usually non-experts in CAD modelling, in particular the assistive product users. The implication is exploring a new dimension for virtual model that could better elicit emotional response will be needed.

## 7 A PROPOSITION

Research related to augmented reality (AR) aiming at either directly or indirectly supporting interaction design has been explored and achieving varying degrees of success [1,2,15,16,17]. AR technology could augment the real-world environment with virtual models in an attempt to assist the designers to visualize and communicate their design ideas. AR-based virtual model integrated with stereographic visualization, and haptic feedback, would provide a relatively realistic interaction with the user. Virtual models enhanced with immersive and interactive sensation projecting some relevant use-contexts could better provoke emotional response when compared with the 2D photos/pictures and CAD models. The implication is visio-haptic AR-based virtual model could serve as a multi-modal stimuli and that could be an alternative applicable in assessing the intensity of user's emotion and thereby assist the users articulate their affective needs.

An ontology is defined as a formal explicit specification of a shared conceptualization [7]. Ontological modelling has contributed into design research in two main areas. It has been used to establish framework to describe the complex and contextual design knowledge. Many ontology models were developed, for instance to describe design process [10], and to structure the complex and implicit design rationale [11]. Ontologies have also been developed as computer-understandable dictionaries of the lexicon in design activities.

As designer needs to gather and understand the insight of user's activities including thoughts, feelings and personal values followed by translating them into a product (prototype) that elicits positive emotional response, a design setting that could assist unleash these affective attributes from user will be essential. Many efforts in the area with respect to modelling emotions with ontology have been carried out in the last decades. For instance, Mathieu [12] described a semantic lexicon in the field of feelings and emotions using ontology. WordNet ontology has also developed an extension called WordNetAffect to annotate emotions [18]. With the support of ontology technologies, a photos database was structured in such a way that users can retrieve the emotion annotated information in a semantic manner [3]. Ontological modelling, by implication, is plausible to structure the implicit and contextual emotions of user to better the communication of emotional response between designer and user.

In light of the importance of the emotional response to a prototype (or product), a setting that could enable user-designer-prototype interaction will be needed. Fulton Suri [6] emphasized design experience as a key influence in conceptualising good designs. A prototyping system that could encourage students (or designers) to establish positive design experience will be essential. This prototype system is envisioned to assist the students (or designers) gather emotions of user, and translating them into a product (prototype) that elicits positive emotional response. The prototyping system is proposed based on a closed loop reflective model as illustrated in Figure 1. The prototype system will integrate visio-haptic Augmented Reality (AR) modelling technique with emotion ontology to create a user-interactable prototyping environment. The prototyping environment will enable designer to simulate the use context that is essential to provoke emotional response to product (which is represented as a virtual model) from user while interacting with the AR-based virtual model. The virtual model is envisioned to support better sharing of emotion data between user and designer to facilitate designer in identifying the user's affective needs.

## 8 CONCLUSION AND FUTURE WORK

This paper summarized the user-centred design approach practiced in a design course, which was offered to students at the tertiary educational level. Some major weaknesses with respect to the UCD approach applied in assistive product design were pinpointed. An integrated design method was proposed based on a reflective design model in which user's emotional response to a multi-modal basis virtual prototype formed the kernel.

The proposition given in this paper lays future development in three key areas: 1) vision-haptic Augmented Reality prototyping environment suitable for laymen users; 2) emotion ontology construction; and 3) affective design for assistive product by getting end users involved in an active role. In-depth study is required to integrate the three areas to make the envisioned prototyping system plausible. The practicality of the system will need to be tested via some real design cases to be carried out as student projects of the design course.

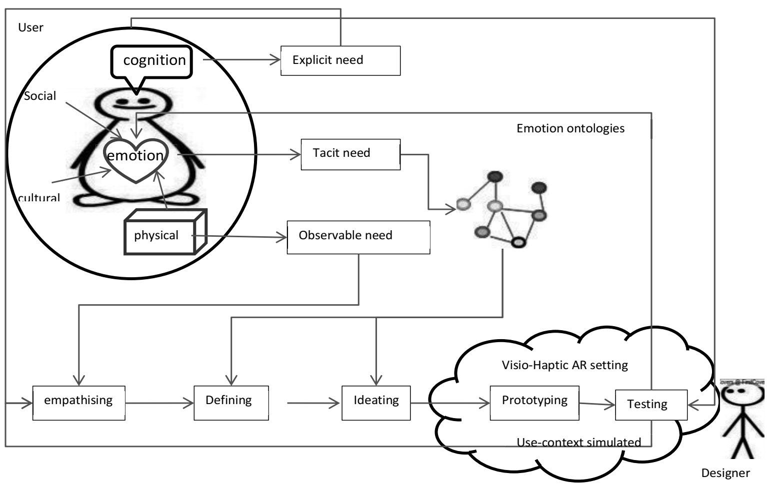


*Figure 1. The Conceptual Model of the integrated design method*

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# ETHICS – RESEARCH, ENGINEERING, DESIGN… THEY'RE ALL THE SAME AREN'T THEY?

**Tania HUMPHRIES-SMTH[1], Gordon BLOUNT[2] and John POWELL[3]**
[1]Bournemouth University
[2]Coventry University
[3]Bournemouth University

**ABSTRACT**
This paper considers how and to what extent product design ethics is understood by professionals in design practice and undergraduate students of product and engineering design and how, if at all, design ethics differ from engineering and/or research ethics. This paper reports on a study carried out at Bournemouth University with undergraduate students of Engineering Design and Product Design and with design professionals via the Institution of Engineering Designers. As part of their final year project work all undergraduate students at Bournemouth University are required to comply with the Bournemouth University Research Ethics Code of Practice [9] which means that students are aware of ethical principles in general and the study explored the extent to which students understand them in relation to design. The study also used the 'LinkedIn' discussion forum to get the perspective of design practitioners. The paper concludes that designers do seem to share a broadly common understanding of design ethics and that the main difference with design ethics is in the scope, complexity and the human interface. A definition of product design ethics is presented and the essence of a Statement of Principles for product design ethics proposed.

*Keywords: Ethics, engineering ethics, design ethics, professional ethics, teaching ethics*

## 1 INTRODUCTION

This paper considers how and to what extent product design ethics is understood by professionals in design practice and undergraduate students of product and engineering design. The paper is closely aligned to the topic – teaching ethics in engineering and design. It is necessary to understand how, if at all, product design ethics differ from engineering and/or research ethics and a common definition must be agreed before it can be taught. The Oxford Dictionary defines ethics as being the moral principles that govern a person's behaviour or the conducting of an activity. Professional ethics are considered to be professionally accepted standards of personal and business behaviour, values and guiding principles. Codes of professional ethics are often established by professional organizations to help guide members in performing their job functions according to sound and consistent ethical principles[1]. The literature review considers the current status with respect to a definition of product design ethics from a professional perspective and compares this with the definition of engineering ethics as being a related discipline. The importance of product design ethics should not be underestimated as every product that is designed and manufactured is sold to a potentially global human market. The impact may be very large and sometimes crucial to survival.

## 2 LITERATURE REVIEW

Considering the professions of design and engineering, it would appear that there exists a comprehensive definition and code of practice related to the engineering profession. Engineering ethics are set out in UKSPEC [2] and in Engineering Council (EC)/Royal Academy of Engineering (RAEng) Statement of Ethical Principles [3]. Specifically the RAEng statement says

"Professional Engineers work to enhance the welfare, health and safety of all whist paying due regards to the environment and the sustainability of resources. They have made personal and professional commitments to enhance the wellbeing of society through the exploitation of knowledge and the management of creative teams."

Four fundamental principles should guide engineers – accuracy and rigour; honesty and integrity; respect for life, law and the public good and responsible leadership: listening and informing. These are further expanded with several sub-definitions under each of the principles.

These principles are reflected in the Institution of Engineering Designers (IED) Engineering Design Specific Learning Outcomes for EC Accredited Degree Programmes: specifically S5 - Awareness and application of a high level of professional conduct and ethical responsibility including the global and social context of engineering design. Additionally, the RAEng produces a document suggesting how ethics might be mapped onto the curriculum [4].

However, the same cannot be found for the design profession. In fact design ethics has a long history, arguably traceable back to the nineteenth century with the likes of William Morris and the Arts & Crafts movement. Blount [5] in 2006 was suggesting an equivalent code of practice was needed for the design profession, and as far back as 1997 Robotham & Blount [11] were discussing the need to include 'Design with Attitude' in engineering designers' education. However, little progress seems to have been made since this time, albeit that the Chartered Society of Designers (CSD) do promote a Professional Code of Conduct for their members [12]. However, this code of conduct largely focuses on principles relating to honesty and integrity and respect for the law. The IED have an equivalent set of Specific Learning Outcomes for Product Design Accredited Degree Programmes and the closest to S5 quoted above are:

"S2p – An awareness of the financial, economic, social legislative and environmental factors of relevance to product design," and

"S3p – awareness of the social and environmental impact and the application of sustainable design principles,"

These do not cover the same breadth as those stated in the RAEng principles quoted previously. Covill et al (2010) [6] discuss an approach to embedding ethics in the engineering and design curriculum in one Higher Education Institution (HEI) but do not focus on what design ethics actually is. Keitsch and Bjornstad (2010) [7] also discuss how ethics is integrated into the curricula and what the ethical criteria should be, but it would appear, their approach is rather focused on issues related to sustainability than a broader spectrum.

Swann in 2002, although not specifically discussing design ethics, clearly articulates that "Design is for human consumption and not bounded by the quantifiable certainties of the physical world…it is in the end usage of a designed product that belongs in the social science world." [10, p51]. Swann goes onto claim that "The act of designing is a problem solving "performance" that is not necessarily the same as research and analysis." [10, p53].

Loo in Felton, et al (2012) [8] sets out a related but more complex picture of ethics as it relates to design, in terms of three orders of ethical consideration. He sets out the three orders as being consequentialist, because he sees designs function as being a mediator of 'people-to-people relations'; deontological, which relates actions to moral codes and finally ethical thinking, based on the concept of virtue which considers values such as truthfulness and humility. Loo sets out the idea "of design as *performative* ethics." [8, p5] and when design is considered to be ethically sound, functional qualities such as accessibility, usefulness and safety are assumed, all of which he claims derive from a 'moral imperative'.

## 3 METHODOLOGY

In order to understand design practitioners' and design students' understanding of product design ethics and enable comparison of this with the literature cited above two separate data collection activities were conducted. They had a common belief in the need for a qualitative approach to ascertain human perceptions and understanding. Thus a qualitative questionnaire was determined to be the most suitable form of tool for data collection. However, the medium used was different and the questions were modified slightly between the two groups of respondents.

### 3.1 Data collection from students

Design students were all studying Product Design, Industrial Design or Engineering Design at Bournemouth University and were all final year students. As part of their final year project work all undergraduate students at Bournemouth University are required to comply with the University's Research Ethics Code of Practice [9]. This means that students are aware of ethical principles in general and the study explored the way they are understood in relation to design. The students were invited to answer a series of questions regarding their own views and experiences of ethical issues:

1 How do you define ethics?
2 Have you ever considered Ethics when working on a design project?
3 What was the area of work / study that you were performing when you considered Ethics?
4 Who in a company has responsibility for Ethics?
5 In what ways could a design be unethical?
6 How does a business ensure that it is being run Ethically?
7 Should your own morals and beliefs affect your professional design work?
8 When have you been taught about design ethics?
9 Where would you look for information on design ethics
10 Would you be part of the design team for a nuclear missile?

There were 92 responses, all of which were written answers to verbal questioning.

### 3.2 Data collection from design professionals

Design professionals were sought from the IED group on the LinkedIn web based discussion forum. They were invited to answer the questions in light of their views and experiences of ethical issues. The questions were the same as those to the students except that question 10 was replaced by

- In the hypothetical context of the design of a toy sword for a child, at what stage should ethics be considered and who and what would be affected by the design decisions?

In addition, an opportunity was added to make any other points on the issue of ethics in design. Narrative expansion of basic answers was encouraged to enable the respondents to express their views freely; this was in full recognition that a wide range of views might be difficult to categorise and thus report succinctly.

The medium was the Survey Monkey ® system. There were 10 responses.

## 4 FINDINGS

### 4.1 Finding for Undergraduate Designers

The ninety two responses: were as follows:

Question 1 (Defining ethics): 38 cited morality, 50 alluded to protecting people, groups and wider society. Examples of the type of response would be

*"The humanistic, environmental, social and economic values that are perceived and recognized as important by the wider culture."*

*"Ethics boils down to intentions"*

Question 2 (consideration of ethics): 73 affirmative replies.

Question 3 (area of work): A high proportion had considered ethics as part of their final year design project but this was only during their research stage which is a compulsory component of their course. Only 17 students indicated that they directly considered ethics during professional design. These consisted of a variety of design jobs designing alcopops, mouse traps, prosthetic limbs, yachts and disposable products.

Question 4 (organisational responsibility for ethics): 75 believed everyone within the company had a responsibility for ethics, 6 believed that management was responsible and 11 of the respondents believed that HR held the responsibility.

*e.g. "At every stage (in design) there are ethical decisions to be made…everyone."*

*"In theory everyone; in practice, only those able to influence ethical decisions in the workplace."*

Question 5 (ways in which a design could be unethical): Offensive (42) , harm the environment or people (30), involve labour or manufacturing processes that infringed human rights (20)

*e.g. "Encouraging negative behaviour, cause harm, kill, deprive, cause damage, exclude, incite hatred or negativity, sexaulise."*

Question 6 (means of assuring ethical operation): as for question 4. Internal policy and procedure (24), ethical guidelines (9), training and independent scrutiny (4).

*e.g. "Constant ethical cultural analysis of the organization"*

Question 7 (the effect of personal beliefs): 42 replies confirming a positive effect.

Question 8 (when have you been taught about ethics): At University (86) which was mainly around ethics relating to research for their final year project, during placement (17), at school (17)

Question 9 (sources of ethical information): Internet/google (74), reference books and journals (28), design professionals and academics (18), IED and RAEng (1)
The group was asked a personal question regarding design ethics. "Would you consider being part of the design team for a nuclear missile." Only 26 said yes. Many felt very strongly that they would not consider it. A small minority said it would depend on the salary!
Overall the responses of undergraduate designers showed that the students shared a common understanding of the concept of ethics and thought that everyone within a company had a responsibility. The majority stated that to be ethical a design should not offend or cause harm during its life. The group did not have a definitive answer as to where to find information regarding design ethics.

### 4.2 Findings for Practicing Designers

The ten responses: were as follows:
Question 1 (defining ethics): 5 cited morality, 3 included the consideration of others, 2 values and standards
Question 2 (consideration of ethics): 10 affirmative replies
Question 3 (area of work): building products, consumer product design (2), building design, medical engineering, architectural hardware, academia (2), chemical engineering, military vehicles.
Question 4 (organisational responsibility for ethics): individual responsibility (6) senior executives (3) ethics officer (1).
*e.g. "The directors ensure that the ethics are instilled in all employees from the induction process forward."*
Question 5 (ways in which a design could be unethical): end use (7), sustainability (both disposability of the end product and the materials used) (2), illegal copying of designs (2)
Question 6 (means of assuring ethical operation): as for question 4. Only one designer reported a specific monitoring of ethics.
*e.g. "We have a number of gateways in the design process which the senior management define and measure the project's progress. At this point there are a number of questions asked of the project leader; some of these questions are based on ethical principles of the company."*
Question 7 (the effect of personal beliefs): 10 replies confirming a positive effect.
Question 8 (have you ever been taught about ethics): 2 affirmative replies, 8 negative ones.
Question 9 (sources of ethical information): libraries (2), the internet (3), no reply (5).
Question 10 (design stages at which ethics should be considered): All 10 believed that ethics had to be considered at all stages in the design process starting at decision to tender, through requirements and concept to user and disposal.
The open invitation for 'other' ethical issues elicited two opposing views on the importance of ethics: one person had almost resigned over an ethical issue, another stated that the need to earn a living is more important than ethics. Overall, the responses of practicing designers showed a deep understanding of the issues, especially the breadth of ethical aspects that a designer has to consider. A number (6) stressed the importance of sustainability but pointed out that this is only one area to take into account.
Some further examples of statements are given below:
*"I do not necessarily know the use of the laboratory equipment I work on... I am pretty sure it isn't used for illicit drug production - but some of it could be."*
*"There seems to be an unending list of social and moral questions we ask ourselves with respect to our projects."*
*"Ethics could be seen as an incredibly grey area, especially in design. It is complex philosophy and very personal."*
*"It's bigger than people think."*.
*"I would remind myself that it was my decision to accept the project or not - I would gently explore if the client wanted to talk ethics or not up front - if they didn't - I might walk away."*
*"If there is very high unemployment and you have a family and a mortgage then survival is more important than ethics."*

### 4.3 Discussion of Findings

The following table 1 summarises the responses given.

*Table 1. Summary replies*

| Question | Student designers | Practicing designers |
|---|---|---|
| 1 (defining ethics) | Morals 38<br>Protecting others 50 | Morals 5 Other people 3 |
| 2 (consideration of ethics) | Yes 73 | Yes 10 |
| 3 (area of work) | 17 fields | 8 fields |
| 4 (responsibility for ethics) | Personal 75 Management 17 | Personal 6 Management 4 |
| 5 (ways in which a design could be unethical) | Offensive 42<br>Harm environment/people 30<br>Infringe human rights 20 | End use 7 Non-sustainable 2 Copying 2 |
| 6 (means of assuring ethical operation) | Internal Policy and procedure 24<br>Ethical guidelines 9<br>Training 9, Intendant scrutiny 9 | Personal 6 Management 4 |
| 7 (the effect of personal beliefs) | Positive 42 | Positive 10 |
| 8 (teaching of ethics) | University 86<br>Placement 17 School 17 | Yes 2 No 8 |
| 9 (sources of ethical information) | Internet 74<br>Books and Journals 28<br>Design professionals/academics 18<br>IED and RAEng 1 | Libraries 2 Internet 3 |
| 10(design stages for ethics to be considered) | Question not asked | All stages 10 |

It would appear that undergraduate product and engineering designers and practicing designers share a broadly common understanding of ethics. Although a limitation of the study is the unbalanced numbers between the two groups it is evident from the statements that the practicing designers gave deep consideration to the questions being posed. As expected the undergraduates did express most consideration of ethics as being related to the research phase of their final year projects as they are specifically required to consider ethical issues in this work by University's Research Ethics Code of Practice. A low number of undergraduates had encountered ethical issues on placement. However, interestingly these all related to the end use of the product: this aligns to the majority of respondents from the practicing designers. Two common aspects of ethics expressed by both groups were morals and protecting others from harm. There was also emphasis of the breadth and complexity of design ethics. These ideas align strongly with the ideas from the literature and would seem to form the potential for a defining the uniqueness of design ethics.

## 5 CONCLUSIONS

From the findings of this study it is reasonable to accept there is a considerable amount of commonality between engineering, product design and research ethics.

However, the defining difference of ethics for the designer is the breadth of the work and the human interface aspects. This difference broadly aligns with the concepts found in the literature, particularly as expressed by Swann [10] and Loo [8] who see product design ethics as being performative and deeply related to mediating human relationships and wellbeing.

Thus, the following definition of product design ethics is proposed:

The designer has ethical responsibility for all aspects of a product's creation. The scope is

- Use/interaction of the product by humans
- Source of components and materials
- Form and function of the product
- Manufacturing methods
- Disposal of the product at the end of its life

Thus, the following Statement of Principles for Design Ethics is proposed which has the four principles of the Royal Academy of Engineering Statement:

- accuracy and rigour;
- honesty and integrity;
- respect for life, law and the public good
- responsible leadership: listening and informing

with the addition of a fifth principle

- recognition of the impact that the design has socially, environmentally and financially in a global context

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## Chapter 11

# INTERNATIONAL COLLABORATION

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
4 & 5 SEPTEMBER 2014, UNIVERSITY OF TWENTE, THE NETHERLANDS

# WHEN GLOBAL DESIGN MEETS EUROPEAN GLOBAL PRODUCT REALISATION -DESIGN TECHNIQUES AND CHALLENGES

**Resham ADVANI, Katherine FROST, Elton GWASHAVANHU, Sara LINDA, Sham RANE, Matthew READ, Mohamoud SAMATAR, Sultan SHAFIQ and Mohammed SHARIF**
City University London, United Kingdom

**ABSTRACT**
This paper explains the effect of group collaboration via distance communication with the emphasis on designing a new product. It furthermore highlights the challenges and barriers encountered during the design phase following the Tuckman model and the methods taken to overcome these challenges.
As a part of the European Global Product Realisation (EGPR) project students were placed in groups to conduct a project with the cooperation of three Universities: City University London with Engineering Design (ED) Students, University of Strathclyde with Product Design (PD) students and the University of Malta with ED students. Project participants were given the task of designing, building and testing an innovative airplane tray table while collaborating in virtual teams. The primary aim was to enhance student's team building experience and communication in order to provide an insight of real life work when undertaking a multidisciplinary design task.
Throughout the project, management and communication were closely recorded; various phases of the project had to be conducted to successfully solve the problem. The phases comprise of research, conceptualisation, detailed design, prototyping and testing. Through each phase students had to exchange knowledge and skills, by exchanging their design tools from their academic orientation leading to an application of combination of tools. This consequently caused some members to fall out of their comfort zone when utilizing unfamiliar processes.

*Keywords: Design process, product design (PD), engineering design (ED), European Global Product realisation (EGPR)*

## 1 INTRODUCTION

A multidisciplinary design task was to be conducted in a collaborative manner between City University London, the University of Malta and the University of Strathclyde.
Five groups of students made of ED and PD were challenged to innovate an aeroplane tray table such that it encompassed mechanisms and configurations that maximised the passenger's in-flight experience and satisfaction. The work had to be performed through distanced communication by employing methods such as video conferencing and social media. Difficulties arose, not just not only due to asynchronous teamwork but also by having different expertise, as students had to complete the task using unfamiliar design tools and processes.
This paper aims to exemplify students' experiences and attitudes towards working in teams of different disciplines; it also presents various phases of design undertaken by students to fully understand the requirements and hence successfully complete the project.

## 2 LITERATURE REVIEW

The EGPR/ Global design project has been running since 2002, and it encloses different design backgrounds including ED and PD. Each year students participating encounter diverse challenges by working with different people as well as performing unfamiliar design tasks, the details on the project and its evolvement throughout the years is presented in [1].
During the previous project, completed throughout the academic year of 2012-2013, students were assigned the task of developing a low cost solar thermal collector. Participants were placed in teams of ED and PD students where they were obliged to employ a wide range of tools and approaches to

complete the project. While conducting the project investigation, it was observed that ED students were more accustomed to analysing the technical aspects of the product while the PD students were more used to focusing on generating concepts and the innovative side of the design. Combinations of both areas of expertise have enabled participants to successfully complete the task. Figures 1 and 2 below highlight the engineering and product design approaches used during the project.


*Figure 1. The engineering design approach* [2]

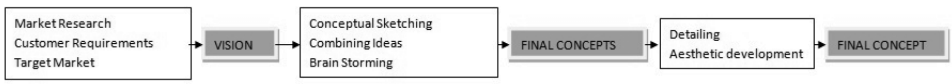


*Figure 2. The product design approach* [2]

Although the project was successfully accomplished, students seemed to be working separately within their comfort zones and were not focussing on the learning of multidisciplinary approaches. After their initial experience, the students participating on the course for their second year running showed a better attitude towards the management and communication aspects. Participants are now often using various means of communications to facilitate the design tasks. Tools such as brainstorming ideas through video conferences or file sharing sites as well as sketches are employed to illustrate ideas and share knowledge between members.

The 2013-2014 project brief required participants to design an aeroplane tray table. At the end of the project an investigation was performed in which the highest proportion (35%) of participants identified communication as the main drawback in successful design. Further results of the study include difficulties with difference in approaches to design methodologies and varying personal outcomes, each represent 20% of the overall challenges. Figure 3 shows the results of the survey for students on the project challenges.

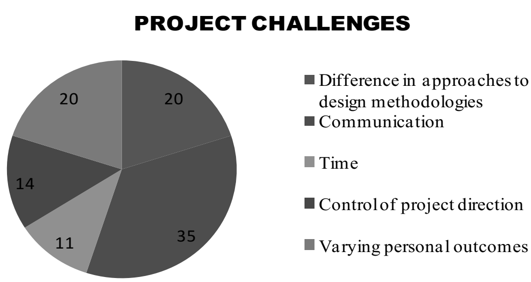


*Figure 3. Challenges faced by students*

## 3 AEROPLANE TRAY DESIGN

Five multinational teams of 8-9 students formed by representatives from each of the participating universities took part in the EGPR design challenge. Each of the teams were expected to develop concepts, detailed design and manufacturing drawings for a prototype of the airplane tray table. Different teams took different approaches to the design challenge opting for diverse design and communication tools and ultimately generating their own solutions.

The early steps of the aeroplane tray design assignment involved carrying out a detailed investigation and gaining an understanding of requirements and desires for passengers. In order to do this, surveys were carried out to reach a large audience, aeronautical engineers from Firefly and Airasia were consulted and research on patents, existing competitors and other factors was undertaken.

Results conveyed that when designing a solution, an emphasis had to be placed on the stabilisation of the meal tray and on maximising space and thus the comfort of the passenger. Besides this, the aim was to develop a multi-functional tray and incorporate aspects of in-flight entertainment to make the system as 'smart' as possible. Currently there are airplane trays such as the ones established by 'Smart-Tray' which integrate a tablet holder in their designs, meanwhile other competitors have focussed their designs on the folding mechanisms of the tray such that the personal space for the passenger is maximised. This is analysed in further detail in the subsequent sections.

# 4 TOOLS AND APPROACHES

## 4.1 Project management tools

Different teams took alternative approaches. Some opted for the traditional organisational structure whereas others chose to share management responsibilities and incorporate a flat/circular management structure. The tools used to effectively manage the project remained consistent with all teams. See management tools in table 1 below.

*Table 1. The design tools used to effectively manage the project*

| Phase | Design Tool | Traditionally Used By | Used To |
|---|---|---|---|
| Management | Work Break Down Structure | ED | Outline all the tasks required and decompose them down to smaller manageable tasks |
| | Gantt Chart | ED/PD | Set appropriate time-scales for the work that has been broken down |
| | Team Calendar | ED/PD | Highlight important deadlines and dates |

## 4.2 Design phases and tools

ED and PD have grown accustomed to different design processes and most groups throughout the duration of the project adopted methods out of their comfort zone and accommodated methods they were unfamiliar with. Table 2 below shows the general methods used during the design process.

*Table 2. The design tools used to achieve the final product*

| Phase | Design Tool | Traditionally Used By | Used To |
|---|---|---|---|
| Problem Definition | Causal Map | PD | Globally brainstorm general user requirements and establish relationships between them |
| | Objective Tree | ED | Order the requirements and rank them in order of importance. Each institution conveyed the weightings of the objectives which were then averaged. |
| | Functional Model | ED | Graphically represent the overall functions of the Airplane Tray Table. These were then broken down into sub functions. |
| | QFD | ED | Establish relationships between user requirements and engineering characteristics. |
| Concept Generatio | 6-3-5 Brainstorming | PD | Generate ideas which were further developed by other team members, over 100 concepts were generated. For some teams this was their primary method for generating concepts, others used the morphological chart. |
| | Morphological Chart | ED | Generate solutions to sub-functions obtained from the functional model. Concepts were then made by using the solutions. |
| Concept Selection | Dot-Sticking | PD | Allow team members to express their preferred concepts by placing dots and narrow down concepts produced in the earlier stage. |
| | Decision Matrix | ED | Rank concepts with respect to the objectives. Each institution collectively filled in the decision matrix constructed and the values were then averaged. |
| | Technical vs. Economical | ED | Further illustrate that the final concept was the best balance between technical aspects (such as performance and reliability) and economic aspects (such as maintenance and installation and operation) |

The methods summarised in table 2 were utilised by all participating groups. One group however chose to experiment with combining available methods and to examine affects the design process itself. This group used the 6-3-5 brainstorming method to generate initial concepts which were then narrowed down using a survey and a decision matrix. The concept chosen was then refined and optimised through the use of a functional model and a morphological chart; the functional model was constructed in the concept generation phase.

### 4.3 Communication tools

One of the most important parts of the project was to effectively manage the synchronous and asynchronous communication methods, to ensure that the team held regular meetings and could share documents while keeping a personal log throughout the duration of the project. The forms of communication used by participants are summarised in table 3 below.

*Table 3. The communication tools used throughout the project*

| Communication Type | Communication Tool | Used To |
|---|---|---|
| Synchronous | Video/Audio Conferencing | Meet with all team members to discuss issues and take the project forward |
| Asynchronous | Texts | Instantly notify members of the group of an update. This was mainly used more when it was more difficult to access social media. |
| | Social Media | Raise any issues encountered. Used heavily for polls when opinions were needed |
| | Email | Initially communicate with team members. This was the least used due to social media and texts |
| File Sharing | Cloud Storage | Share files and manage information. This allowed team members to work on the same files at different times |

## 5 CHALLENGES AND CONSTRAINTS

### 5.1 Difference in approaches to design methodology

On one hand Mechanical Engineering students were more familiar with the ED Process with its sequential nature and tools, which they normally used such as Gantt chart, Work Breakdown Structure, Objectives Tree, Functional Model, Quality Function Deployment, Morphological Chart and the Decision Matrix. On the other hand the PD students used more of an 'artistic expression' approach which focused on group brainstorming using the 6-3-5 method to generate design concepts. Many PD students found the ED Processes too technical and tedious. In some groups, especially evident during the 'storming phase' [4], this resulted in an impasse when it came to intra-group team working and defining the project direction. One common and detrimental result, which was noticed, was that students formed sub-team based on their location and though work was being done, there was a lack of overall team cohesion.

### 5.2 Communication

It is vitally important for the success of a project that the team members get to know and understand each other from the very beginning. A multitude of asynchronous modes of communication were at the disposal of all students including e-mails, social media platforms such as Facebook and Whatsapp, SMS, Google Drive and The Box. These were quite trouble free in all groups. Synchronous communication methods were also vital and these included Jabber as the primary means and also some groups made use of Skype and Google Hangouts to establish video conferencing, which was necessary because of team members being in different geographical locations. However the groups reported technical difficulties establishing a good connection, especially on Jabber, due to poor hardware connections at one of the universities. A tight booking schedule for Jabber meant any time lost was nearly impossible to make up for. Of particular note, team-forming meetings were badly affected. Skype and Google Hangouts were both used extensively in all the groups but usually suffered poor connectivity. Therefore the bulk of group communications was asynchronous and this adversely impacted on group dynamics and subsequent work that followed.

### 5.3 Time

The project duration was scheduled for ten weeks. For all students involved in the Global Design project, this was just one of a number of academic commitments. Outside of the timetabled lectures it was quite difficult to find additional time that suited everyone's other commitments, both personal and academic. To varying extents in each group, particularly during the 'performing phase' [4], this slowed down progress and affected the quality of work produced.

### 5.4 Control of project direction

This proved a challenge due to different approaches to the design process. Since students from the University of Strathclyde outnumbered all others in every group their influence in the decision making process was thereby strong and they tended to dominate the major aspects of strategic planning. This sometimes led to discord in finding common ground to merge the different design methodologies into one effective process; hence the project progressed with a two-pronged approach with little collaboration. This counter-productive situation happened in most groups during the 'storming phase' but was resolved later and allowed the group to progress to the 'performing phase' [4].

### 5.5 Varying personal outcomes/objectives

This had quite a serious impact on the project outcome. Students at different Universities had varying academic weighting to the project i.e. the number of academic credits attached to the project. For most it was part of their final year module set and carried significant academic weighting but for others, the project did not carry any academic credits. Though the overall project deliverables were the same for all students, Strathclyde students evidently felt they would be assessed primarily on generating concepts through brainstorming and then developing the best concept without much focus on the more technical detail of the product. Naturally this affected group dynamics because levels of students' commitment to the project as a whole and to certain aspects within the project greatly varied. This difficulty was not totally solved but the level of student's engagement to the design tasks increased after the forming phase. Many participants have mentioned that this was one of the major issues and academics are considering having equal weighting for all universities in future projects.

## 6 OUTCOME

Upon completion of the conceptual design phase, the concepts, which had the best potential for becoming a high-calibre product, needed to be identified from the assortment of generated concepts. This was done by comparing each of the concepts with the objectives/requirements set in the problem definition phase. The dot sticking and decision matrix were the main methods employed to evaluate how well a concept fulfilled the requirements. The dot sticking method was based on preference while the decision matrix was based on quantitative evaluation of each concept. The PD students predominantly used the dot sticking method but the ED students preferred the decision matrix. Figure 4 shows the final design of all the teams, it can be seen that the final designs tended towards multi-functionality and in-flight entertainment.

| | Team 1 | Team 2 | Team 3 | Team 4 | Team 5 |
|---|---|---|---|---|---|
| Final Design |  |  |  |  |  |
| Main Features | Eating and being able to operate an e-device simultaneously | Increased surface area for extra storage, contemporary style with an acrylic finish | Extra shelf on top for holding personal items, lamp may be fitted under shelf | Separate tier integrated with main tray can be folded out | Adjustable tablet/book holder for optimised comfort |

*Figure 4. The final designs*

The students participating in the global design project grasped the different ways of approaching a problem as they were exposed to design tools used outside of their respective disciplines. Resolving conflicts effectively helped to build a foundation of trust and mutual respect between team members. The project also provided the students with a valuable opportunity to improve their communication skills by actively listening to team members, expressing their own ideas and providing constructive feedback.

## 7 CONCLUSION

The challenges of designing, building and testing a new product were faced and successfully overcome through the collaboration of students working in decentralised teams. It was discovered that students experienced some anxiety when confronted with new, unfamiliar techniques and faced various challenges while working distantly through means of virtual communication. This has contributed to the students learning and development.

Working in virtual teams is a vital aspect of academic learning and experience; participants expressed that this group project has enhanced their knowledge and skills essential for tackling the challenges of future employment, particularly when confronted with working in multidisciplinary and multicultural environments and when adopting unfamiliar tools.

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# AN ASSESSMENT OF INTERNATIONALIZATION IMPACT ON ENGINEERING EDUCATION QUALITY SCORES: A BRAZILIAN CASE STUDY

**Anderson Edilson PRESOTO, Isabela Mantovani FONTANA and Roberta SOUZA**
University of São Paulo, Brazil

**ABSTRACT**
Internationalization is a trend topic in terms of research, including in engineering education. It is a consensus in the academic literature that competitive advantages are related to the development of skills considering internationalization. The objective is to provide an assessment of the internationalization impact on different education quality scores, taking as proxies well established rakings. Multivariate methods are used to estimate the importance of each variable in education quality score. The coefficients of a regression model are employed to ponder the relative importance of internalization on quality assessments. Going further, the impact of largest program of internationalization, "Ciências sem Fronteiras", after almost three years of its creation, is evaluated. Furthermore, comparative analysis is conducted to trace how Brazil behaves compared to other countries. Finally, the analysis focus strictly on the engineering domain, taking into account the specificities associated, such as the technical expertise which may be developed with internalization process and the real impact on economics aspects. The findings highlight clearly the importance of internalization indexes as majors explicative variables to quality assessment scores.

*Keywords: Internationalization; engineering education; education quality scores*

## 1 INTRODUCTION

Globalization is a term that has long and ever increasing importance. A search conducted at ISI Web of Science database is a proof that between 1985 to 2012, the number of scientific production per year with the term globalization started at 2 till more than 3000. That points out the evolution of publications with this term during the last years. As stated at the Millennium Report from United Nations, in 2000, Globalization should be faced as the greatest challenge that everybody is concerned, as it is present everywhere, and it is needed to ensure that globalization becomes a positive force for the entire world's people, building inclusive globalization.

It is also stated [1] that trends seem to suggest that globally integrated strategies are also the wave of the future for industries. In the case of Brazil, in the year of 2001, the country emerged from economic stagnation to a state of decision to link its economy to the global economy, following a new philosophy hallmark of global thinking of a flattening world, whereas there is no more considerable distance and differences across countries almost disappear [2].

In this direction, the internationalization of education follows the same pattern of growth associated with the great need for a paradigm shift in higher education institutions (HEIs). Authors claim that internationalizing the curriculum of a HEI involves providing students with global perspectives of their discipline and giving them a broader knowledge base for their future careers. This internationalization can also help to provide them with a set of values and skills to operate in diverse cultural environments; skills often labelled as "intercultural competencies" or "cross-cultural capabilities". Graduates today will need the resilience and competencies to communicate and compete in a rapidly changing, complex global workforce and world [3]. HEIs around the world are experimenting with different strategies to foster internationalization and networking, achieve critical research mass, and strengthen innovation and labour market integration [4].

In consonance with the internationalization trend, the Brazilian government created "Cuenca seem Frontiers" (CSU) - Science Without Borders - which is a program that seeks to promote the consolidation, expansion and internationalization of science and technology, innovation and competitiveness through an exchange and international mobility. The project involves the use of up to 101 thousand scholarships over four years to promote exchanges, so that undergraduate and postgraduate can perform internships abroad in order to keep in touch with competitive educational systems in relation to technology and innovation. Moreover, seeks to attract researchers from abroad who want to settle in Brazil or establish partnerships with Brazilian researchers in priority areas defined by the program, and create opportunity for researchers from companies for specialized training abroad.

Nevertheless, many questions may be pointed out about this matter, such as: What are the impacts of these programs in the quality assessment of education? What are the differences noticed when compared Brazil with developed countries and other emergent countries? Is Brazil getting positive results from this policy? The main objective is to provide an assessment of the internationalization impact on different education quality scores, taking as proxies well established rakings and general figures issues from surveys. Multivariate methods are used to estimate the importance of each variable in education quality score. The coefficients of a regression model are employed to ponder the relative importance of internalization on quality assessments. Going further, the impact of CsF, after almost three years of its creation, is evaluated.

This article is structured in five sections. Section 1 presents the context and purpose of the research. In section 2, the theoretical background of the research is presented. Section 3 presents the details of the method employed, and section 4 presents and discusses the main findings of the research. Section 5 provides the key findings of the research, followed by the interpretation of the main results. And finally the contribution to the field, as well as the limitations of this research.

## 2 THEORETICAL BACKGROUND

Educators in Brazil hope that the program Ciência sem Fronteiras, (Science without Borders) will be a landmark in the policy of improving the academic quality in the country. The experience to be gained in countries with educational excellence is important but, for the purpose of internationalisation of Brazilian education, it is also necessary to attract teachers and students to our shores and not just send those abroad [5].

Internationalization has a great importance for the quality of teaching and research university. By forming partnerships with institutions abroad opens doors to new ideas and possibilities, and even for new search tools. The quality of work is greater, and the impact of the vehicle for the dissemination [6]. The acquisition of competences is, also, vital for internationalization. The opportunities open to exchanges and such is vital for strengthening national companies [7] and the recruitment of talent, such as students, staff, researchers and academics, from global markets is imperative as is the development of high level critical skills. Students have to be trained to participate in the international context and be assured that it is provided to them the best opportunities available to lead from the front and to leave a global footprint in their trail [8].

There is a necessity to explore the new means of knowledge sharing and appropriation across geographic and intellectual borders. It is needed to provide platforms for the development of multinational, multidisciplinary, multi-sectoral intellectual projects that generate the high level and scarce skills required to address development in our country and on the continent, while it is fostered intellectual communities and promote sustainable social and economic development in a globally competitive environment [8].

## 3 EXPERIMENTAL METHOD

Quality of education can be measured in several ways. In this research, is taken as reference a ranking produced annually, qualifying universities observing a certain set of variables. Bowman and Bastedo [9] highlight the continuous increase of ranking using to compare college and university within a country and around the world. According to [10], its conception is due to the massive expansion of higher education around the around and, by consequence, the interest of society to differentiate institutions from one another in a growing and complex world. Elsbach and Kramer [11], Espeland and Sauder [12], Sauder and Espeland [13] pointed out that these ranking seem to have a particularly influence on decision making process in professional schools and postgraduate programs. Bastedo and Boeman [14] indicate, through empirical evidences, that resource providers who are vulnerable to aspects linked to status hierarchy of higher education are significantly influenced by rankings.

Among the different factors that are taken in account, it is possible to list: research excellence and its influence, measured, for example, by the number of scientific publications and number of citations that they received, under graduated and graduated success in terms of career, number of exchange students. These ranking incorporate a widely range of data sources, issue from different surveys. In fact, the methodology adopted is not uniform, what is fostering criticisms regarding the lack of consensus [9].

For the purposes of this paper, data from one higher education ranking will be used as proxis to quality performance measure: Timer Higher Education World University Ranking. Along with Academic Ranking of World Universities, these two ranking are taken as the three most influential international university ranking [15, 16, 17]

Published by the British magazine Times Higher Education (known as THE), the Times Higher Education World University Ranking (henceforth THE), is an annual world university ranking, which employs in its analysis data from Thomson Reuters, in special, citation database information. The first rankings were released in 2009, jointly with QS World Ranking, partnership that ended in 2011.

In a first moment, Pearson Correlation test will be employed to test the statistical hypothesis of correlation between the overall score (understood as a quality measure) and internationalization score. This test will be anticipated by a Kolmogorov-Smirnov test to test the adherence to Normal distributions assumptions. In case of rejection, Spearman correlation will be employed. This first analysis will be completed by a multiple linear regression, where the variables that compose THE ranking will be used to predicted the overall score, if the assumptions of linearity of the phenomenon measured, constant variance of the error terms, independence of errors terms and normality of the error term distribution may be noticed (HAIR). This analysis will enable to verify the coherence in the terms of influence each variable in the overall score. A conclusion expected from it is the statement of internationalization in terms of quality. It is important to mention that the analysis will be restricted to the ranking regarding Engineering & Technology faculties.

In a second moment, the official figures of "Ciência sem Fronteira" will be crossed with other quality assessment. Data from scholarships that have been granted to students participate in exchange programs were collecting from official documents. The focus will be the engineering students, since the priority of this program is this area, as already explicated above.

The impact of this program, in the Brazilian reality will be verified comparing these data with the official evaluation promoted by the governmental agency CAPES, that each 3 years evaluated, based on different factors, each the most important is the academic production, of all graduate programs in Brazil. Using the same methods proposed above, correlation analysis, and the empirical data will give some important information, enabling also compare the finding from world behaviour with national ones.

## 4 RESULTS AND ANALYSIS

The analysis here proposed starts with the world rankings, with the aim of detecting, in this first moment, the relationship that may be established between quality scores and internationalization degree. Before conducting the analysis, the assumptions of normality are tested using Kolmogorov-Smornov test. It performs a test of a null hypothesis that data follow a normal distribution. The results gotten are illustrated by the Figures 1 and 2. From a graphical perspective, it is possible to notice that the first variable, overall score, does not follow a normal distribution. Regarding the internationalization variable, it follows a normal distribution in its turn. These findings are confirmed by the p-value from the hypothesis test that is less than 1% for overall score, the α-level chosen in all this study, and higher than 10% for the second variable. Having in mind these results, the correlations will be based on a nonparametric correlation, Spearman's Correlation.

Performing the correlation analysis, the following matrix of correlations is obtained (Table 1). If an α-level of 1% is adopted, it is not possible to reject the null hypothesis of non correlation. The conclusion will be different if 5% α-level is suggested. What is very clear from the data analyzed is the fact that the other variables, such as Teaching and Research seem to be far more important, in terms of influence, in the overall score. For the purposes of this study, the data from the top 100 universities were used. This finding enables us to conclude that internationalization is not a key point as determinant of quality scores. Other variables are at stake, more clearly correlated. Once again, the results are directly visible comparing the different Scatterplot illustrated on Figures 3, 4 and 5.

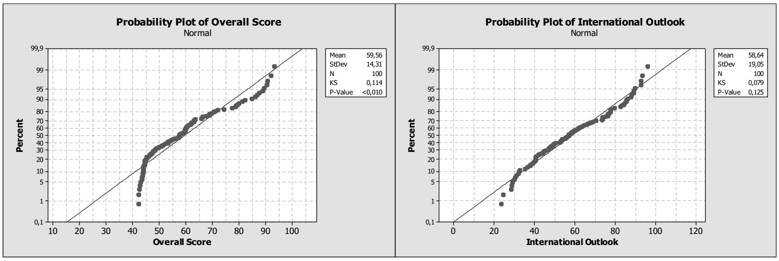



*Figure 1 and 2. Normality assumption tests using Kolmogorov-Smirnov. Source: Authors from Minitab Software*

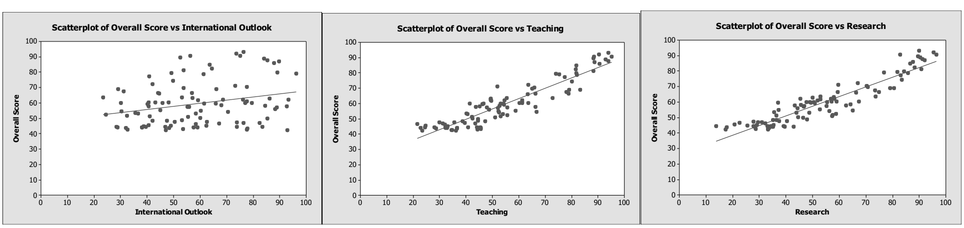
*Table 1. Correlation Matrix using Spearman's Correlations. Source: Authors from SPSS software*

| | | | Overall Score | Teaching | International Outlook | Research | Citations |
|---|---|---|---|---|---|---|---|
| Spearman's rho | Overall Score | Correlation Coefficient | 1,000 | ,894** | ,232* | ,917** | ,456** |
| | | Sig. (2-tailed) | . | ,000 | ,020 | ,000 | ,000 |
| | | N | 100 | 100 | 100 | 100 | 100 |
| | Teaching | Correlation Coefficient | ,894** | 1,000 | ,091 | ,945** | ,130 |
| | | Sig. (2-tailed) | ,000 | . | ,369 | ,000 | ,199 |
| | | N | 100 | 100 | 100 | 100 | 100 |
| | International Outlook | Correlation Coefficient | ,232* | ,091 | 1,000 | ,104 | ,194 |
| | | Sig. (2-tailed) | ,020 | ,369 | . | ,305 | ,053 |
| | | N | 100 | 100 | 100 | 100 | 100 |
| | Research | Correlation Coefficient | ,917** | ,945** | ,104 | 1,000 | ,165 |
| | | Sig. (2-tailed) | ,000 | ,000 | ,305 | . | ,101 |
| | | N | 100 | 100 | 100 | 100 | 100 |
| | Citations | Correlation Coefficient | ,456** | ,130 | ,194 | ,165 | 1,000 |
| | | Sig. (2-tailed) | ,000 | ,199 | ,053 | ,101 | . |
| | | N | 100 | 100 | 100 | 100 | 100 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

While overall score presents a mean 59.558 with a standard deviation of 14.31, international outlook, the variable that are concerned with all aspects linked to international points, has a mean of 58.644 and standard deviation of 19.05. The values do not signal a statistical different among these figures. In fact, using Wilcoxon signed ranks test this empirical evidence is confirmed.




*Figures 3, 4 and 5: Scatterplot between Overall Score and Internationalization, Teaching and Research respectively. Source: Authors from Minitab Software*

Stricting the multiple regression model, it is equally possible to generate a regression using the data collected. Despite the fact that two variable, teaching and research, present a significant correlation, that implies problems of multicolinearity, the other assumptions can be reasinealbe statisfected. Ignoring the aspect pointed, performing the multiple linear regression, we achieve in the equation used by THE to compute the overall score.

```
Overall Score = 0,078 + 0,305 Teaching + 0,0742 International Outlook
              + 0,0501 Industry Income + 0,295 Research + 0,275 Citations
```

With R-squared - adjusted of 100,0%, the calculation promoted by THE favours Teaching and Research. Different from first findings, the set of analysis performed until this moment points out that internationalization factor is not the most significant in terms of participation of overall computing, not even the differentiating element that explain the better results from the Top Universities. It is interest to mention that if the spectrum analyzed were reduced to only the Top 20 universities in the 2013 ranking from THE, the findings are more net: the hypothesis of non correlation between overall

score and international outlook results in a p-value of 12%, making it impossible to reject this hypothesis at reasonable levels of significance.
Once it was not possible to establish a clear correlation between quality measures and internationalization, taking as basis the THE world universities ranking, a second approach is performed regarding the Brazilian scenario, using the program “Ciências sem Fronteira” as objet. The number of students that received scholarships since its implementation is taken as proxis of degree of internationalization. From the other side, the quality performance will be approximate by the official evaluation of graduated program. The results from 2008-2010 and 2011-2013 are considered.
As the first group of analysis, the assumptions of normality are verified. Even so, the hypothesis of normality is rejected. The sample counts with 113 Brazilian institutions, from different regions, ports and areas. The total number of students as well as the students from engineering and technological fields was collected. On average, 327.35 students received the scholarship by institution, being 139.99 from engineering and related areas, as indicated on Table 2.

*Table 2. Descriptive Statistics. Source: Authors from SPSS software.*

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Students by Institution | 113 | 1 | 3332 | 327,35 | 509,831 |
| Engineering Students by Institutions | 113 | 0 | 1179 | 139,99 | 218,503 |
| CAPES results 2013 | 113 | 3,0000 | 5,5000 | 3,827478 | ,5759891 |
| CAPES results 2010 | 113 | 2,5000 | 5,4200 | 3,666106 | ,6029428 |
| Score difference | 113 | -1,000 | 2,500 | ,16137 | ,386409 |
| Valid N (listwise) | 113 | | | | |

Moved by the same logic already employed above, it is possible to conduct a correlation analysis. The results are shown on Table 3. It is possible to conclude that there exists a significant correlation between the number of students granted (considering the total number or just students form engineering related fields) and the results gotten in 2010-2013 graduated evaluation. It indicates that the courses that are better evaluated have been receiving more attention when the scholarships are distributed. Nevertheless, regarding the effect of this expressive internationalization program in terms of improvements may not be noticed yet. There is no significant correlation between the difference computed between the current and former evaluation. Moreover, the results signalized that further investigation may be valuable, once a negative correlation is obtained, an indication of a total unexpected result.

*Table 3. Correlation Matrix using Spearman’s Correlations for Brazilian Case. Source: Authors from SPSS software*

| | | | Students by Institution | Engineering Students by Institution | CAPES Results 2013 | Score Difference CAPES 2010 and 2013 |
|---|---|---|---|---|---|---|
| Spearman's rho | Students by Institution | Correlation Coefficient | 1,000 | ,925** | ,480** | -,177 |
| | | Sig. (2-tailed) | . | ,000 | ,000 | ,061 |
| | | N | 113 | 113 | 113 | 113 |
| | Engineering Students by Institution | Correlation Coefficient | ,925** | 1,000 | ,421** | -,103 |
| | | Sig. (2-tailed) | ,000 | . | ,000 | ,275 |
| | | N | 113 | 113 | 113 | 113 |
| | CAPES Results 2013 | Correlation Coefficient | ,480** | ,421** | 1,000 | ,192* |
| | | Sig. (2-tailed) | ,000 | ,000 | . | ,041 |
| | | N | 113 | 113 | 113 | 113 |
| | Score Difference CAPES 2010 and 2013 | Correlation Coefficient | -,177 | -,103 | ,192* | 1,000 |
| | | Sig. (2-tailed) | ,061 | ,275 | ,041 | . |
| | | N | 113 | 113 | 113 | 113 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

## 5 CONCLUSION

The data analyzed shoed that other variables, such as Teaching and Research seem to be far more important, in terms of influence, in the overall score of HEIs. Other variables are at stake that is more clearly correlated. Different from first findings, the set of analysis performed in this paper points out that internationalization factor is not the most significant in terms of participation of overall computing, not even the differentiating element that explain the better results from the Top 100 Universities studied.
Since it was not possible to establish a clear correlation between quality measures and internationalization, a second approach is performed regarding the Brazilian scenario, using the program CsF as object. The findings highlight clearly the importance of internalization indexes as majors explicative variables to quality assessment scores. Observing Brazil results, many positives points may be mentioned, nevertheless many others points move away from best practices employed

by developed countries, even emergent ones. It indicates that the courses that are better evaluated have been receiving more attention when the scholarships are distributed. Nevertheless, regarding the effect of this expressive internationalization program in terms of improvements may not be noticed yet.
The quality measures have reference to the CAPES evaluation, however this review is restricted to graduate courses only. Despite the graduate programs are fully connected to academic research, one of the central goals of CsF, be restricted only to postgraduate courses can be considered as a limitation to this research. Moreover, the results signalized that further investigation may be valuable, once a negative correlation is obtained, an indication of a total unexpected result.

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# CONTAINER CHALLENGE – PROTOTYPING DISTRIBUTED COLLABORATION

**Joona KURIKKA[1, 2] and Tuuli UTRIAINEN[1,2]**
[1]Aalto University School of Science
[2]Current Address: CERN, European Organization for Nuclear Research

**ABSTRACT**
This paper describes the process and results of "Container Challenge", a remote collaboration exercise that was designed to help global, multi-disciplinary teams to prototype their online collaboration tools while they were still co-located during a course kick-off at CERN.
The exercise was organized in the first week of advanced product design course called Challenge Based Innovation, where the multidisciplinary students from countries around Europe met each other for two weeks to start a five-month long collaboration.
The teams worked on a short design challenge in "containers" that simulated the coming division they would encounter after travelling back to their home universities. The purpose of the exercise was to help the teams to use prototyping and iterative design methods, not only on products and services, but also while designing their own working process.
The previous experiences from similar courses has shown to authors, that a dedicated exercise would be needed to guide the teams to actually test and improve their collaboration plans during their first two weeks together. While there was no statistically significant comparison, the implemented Container Challenge -exercise seemed to have positive effects in developing collaboration plan; the challenge brought out several issues related to distributed work, including the need for virtual empathy and occurrence of increased complication when reflecting on the design activities. It also managed to serve as a shared learning experience that could be used to improve the future collaboration of the teams.

*Keywords: Online collaboration, prototyping, product design, communication planning*

## 1 INTRODUCTION

The act of design is all about bringing something new into life. When conceiving such novel solutions, one of the methods often utilized by designers, is prototyping. Through prototypes the role, look, feel and the integration of different separate parts of the product takes shape and crystallizes.
The authors of this article have a long history of facilitating distributed design team projects with universities like Stanford, Aalto, and HSLU utilizing methodology stemming from Problem-Based Learning [1] and learning by doing [2, 3]. The question they wish to explore in this article is related to the applicability of prototyping to different parts of the design process itself. Could this rapid small scale, low resolution "build it and test it" approach be a useful tool also beyond the typical product and service design processes?
A recurring problem the authors have faced while coaching student teams, is coordinating distributed design teamwork, as online collaboration tools tend to increase the amount of misunderstandings during the process. This article describes an attempt to transform the static collaboration plan devised by the teams into a dynamic prototype to fail fast in order to keep developing throughout the class.

### 1.1 CERN, IdeaSquare and Challenge Based Innovation

The European organization for nuclear research, CERN, is one of the world's largest and most respected centers for scientific research located in Geneva, Switzerland. During its 60 years of existence, CERN has been making scientific discoveries that have increased our understanding about the structure of the universe.

Since early 2013, both authors have been involved in a pilot project at CERN that started as a collaborative feasibility study with Aalto Design Factory few months earlier. The pilot project, currently running under the working name IdeaSquare, is building a new creative work environment to support collaboration within selected particle detector R&D projects. In addition, IdeaSquare aims to increase the societal impact and collaboration with possible external partners, like SMEs and universities.

One of the first pilots of creating impact to the society is an advanced product design course Challenge Based Innovation (CBI) that is aimed for master level students around Europe. The structure and pedagogical background of CBI owes a great deal to several other similar course formats that the authors and the rest of the teaching team of the course has been involved in, most notably Stanford University's ME310 [4] and the overall PBL variation described as Model II by Savin-Baden [5]. CBI includes prototyping and testing solutions, heavy user engagement and it aims to combine novel technology and a human centered approach. Some of the typical course phases of the design process include problem re-definition, need finding, benchmarking, ideation & selection and finally prototyping and testing. However, the teaching focuses heavily on *how* these activities are performed.

The first round of CBI ran from 28.10.2013 to 7.3.2014 with 17 multidisciplinary students, and all the empirical data for this paper was collected during the first two-week intensive period that launched the course. Purpose of this two weeks intensive period was to introduce design thinking methodology to the students and allow the students from different countries to meet each other physically. In addition to the first two weeks, the students have travelled to CERN in 3 other intensive periods, in total for 7 weeks. Rest of the time they have been working together remotely from their home universities in Finland, Greece and Italy.

The starting points of the team members were really heterogeneous. Some of them had already gone through several global collaborative projects and learned how to use the tools in practice, as others had only theoretical knowledge of the topic.

### 1.2 Online collaboration

As the total common time at CERN was only 7 weeks, most of the team work was done remotely with various online collaboration tools. Computer-supported distributed collaboration has been used in engineering design for decades [4i] and the advancing technology and faster network connections are creating more alternatives for a distributed team to collaborate with. However, the amount of alternatives is also a problem, especially for newly formed teams that don't have previous experience about the collaboration tools they are about to start using. The newness of the technology can cause more challenges in the teamwork than all the other factors in a newly formed team [6].

In addition to the technical challenges, coordination and communication are major issues affecting the performance of a distributed design team [7]. Compared with their face-to-face counterparts, computer-mediated teams viewed their discussions as more confusing and less satisfying, spent more time devising decisions, and felt less content with their outcomes. [8]

Meeting all the remote members face-to face has been shown to be one of the best ways to improve these negative effects that the technology and distance can cause to the group performance [9, 10]. In addition to countering the negative effects, the early physical meetings are also increasing the overall effectiveness of the following online collaboration [11].

## 2 THE PROBLEM WITH ONLINE COLLABORATION PLANS

Fluent online collaboration is a crucial ingredient for the success of the student teams. What we usually see in projects like CBI, is a preliminary online tool selection and remote collaboration plans that are put to action only when the teams move to distributed locations. The selection of tools is superficial and problems are not noticed during the kick-off - in other words the teams make their best guess and don't have the chance to put the plan to the test. We often prompt students to test their tool setup during the kick-off week, but subtle reminding has not been enough to disrupt this pattern of team behaviour.

This means that the problems often occur after the project has been running for a while and the teams have started implementing their online collaboration plans in their home universities. Sometimes changes are made to the plan, but unfortunately these changes usually occur late into the project and a lot of time is lost in improving and finding alternative tools to fill the gaps in the original selection.

Figure 1 illustrates the difference between the typical tool selection and implementation process to one aimed with Container Challenge.


*Figure 1. Comparing typical behaviour to container challenge*

### 2.1 Surfacing problems with Container Challenge

To overcome this gap, the authors created a short exercise with the aim to help the teams to transcend from making static and theoretical collaboration plan to dynamically prototyping and testing the plan.
In order to offer an experience of what remote collaboration is like while the team members are still co-located, we organized a special challenge. The teams were taken through the one-hour exercise in separate spaces or "containers" during the first intensive week in CERN. The aim was to simulate a distributed working experience, observe arising problems and through reflection improve the teams' online collaboration plan.
The challenge set to the teams was selected so, that it would be meaningful for their process and that it would encompass most of the elements of the design process: re-defining the problem, ideation and building a prototype [12]. We wanted to offer a variety of activities, since the diverse exposure could allow a maximum amount of problems to surface. For this particular exercise the teams were asked to create a team poster considering the elements described in Figure 2.


*Figure 2. Task definition*

The teams were given an hour to complete the task and then share the results to the whole class immediately after completion. During the exercise the students were divided into four different spaces ("containers") to simulate their future distributed working environments:

- Team Finland 1
- Team Finland 2
- Team Greece 1 & 2
- Team Italy 1 & 2

The teams were not allowed to meet physically during the exercise to simulate an authentic distributed situation. Communication between different locations was limited to maximum of 20 minutes of synchronous global working with voice and video between the whole team. Cutting the time for global communication was done to stress that the meeting time with the whole team is often limited and should be treated with consideration.

## 3 TWO LEVELS OF REFLECTION

To facilitate learning from the experiment, two levels of reflection were introduced. After the challenge, the teams gathered together and presented their process and results. These presentations were used as a base to open up a reflective dialogue amongst the whole class and pick up specific themes and problems that the students just experienced. This allowed the students to share their experiences and to understand the events from other viewpoints.

Another layer of reflection was added a week later, when the each student participated in a private semi structured interview. The questions posed were focused on the individual and team level learning, changes in their team roles and changes in their collaboration plans.

*Figure 3. Presenting the results*

### 3.1 Collecting data

The base for the data gathering was the whole class of Challenge Based Innovation 2013 that participated in the container challenge - 17 students in 2 teams. Each individual sub-group session was recorded on video by the moderators during the Container challenge. The videos primary function was to serve as memory support. The semi-structured interviews described in the previous chapter were conducted in one afternoon by two parallel interviewers in English. All the individual interviews were also recorded on video for further analysis. These results will be analyzed and discussed in the next chapter.

## 4 RESULTS

### 4.1 General

The teams experienced some challenges while making the collaboration plan, as the distributed collaboration looks quite different in theory and practice. One of the biggest mentioned benefits of prototyping the collaboration in the container challenge was bringing the team to a common ground and giving them shared experiences on the online collaboration for further planning - "I understand that the problems I have studied really exist, not only in theory" "Now I have learnt the practice".

In the interviews, several themes emerged regarding the students experiences. Three frequently mentioned key points were the following:

- Communication and reflection of the activities gets more laborious and needs dedicated time
- Gaps/silent parts of the communication need to be interpreted correctly to avoid negative interpretations
- New communication channels pose different benefits and challenges

### 4.2 Communication & reflection of the activities

The students experienced, that designing the poster and on the other hand communicating what was being designed was more laborious than while working around the same table. Some felt, that communication was actually contradicting the making, since they had to stop their work in order to be able to communicate, share and exchange feedback in the "global" sessions. One of the students concluded, "I learnt that communication and doing should be split into two separate parts. It is sometimes hard to do all at the same time." Reflection, one of the key parts of learning, was also seen as more challenging than before actually implementing it.

## 4.3 Interpretation of silent gaps

Several students experienced that the silent gaps during work might be misinterpreted as not caring about the project or slacking off: "Group members should know, that it is silent in the other end because they are focused on doing". Also, differences in tool usage might result in confusion: "If I don't immediately reply on Facebook it's not because I don't care - I go there only once a day so there might be a gap in my response". There might also be other reasons for delayed response time due to asynchronous nature of the communication "In virtual work it takes longer to answer - I want to make sure people understand me and what I mean since they might not ask even if they don't understand me."

## 4.4 Different communication channels

One of the students stated, that using the technology is not the problem, but chatting in English might be very uncomfortable. One of the positive effects of the distributed work environment was getting the native language back. The language was seen to have an effect on a deep level as "Changing the language made working really effective - there were no cultural and language barriers and less conceptual differences." The virtual environment introduced two new channels - text chats and video. Leveraging the additional channels allowed some unheard voices to emerge - "Through writing you could be heard even stronger than talking". However, sharing visual material was seen as more challenging. Even though the online tools had options like screen sharing, they were not familiar to all of the participants. This led to creative solutions, as for example one of the students considered using a mirror to be able to show his computer screen through the video connection.

# 5 DISCUSSION

Based on the interviews, it is safe to say that the prototyping the remote collaboration process with the container challenge managed to bring out some of the problems related to virtual work. The students realized that the communication of their design efforts is a time consuming, yet important step. In a co-located work environment, seeing what other team members are doing and exchanging a few sentences is a light and intuitive way to keep track of the progress. It seems as the challenge also brought out an important need in the virtual environment - empathy. As the lag in communication can be interpreted as negative, there needs to be a strong emphasis on positive thinking and understanding the reasons behind the lag. Since the virtual work brought out some problems (e.g. sharing visual material) and new solutions (e.g. having two layers in discussions with video and text chat) the teams had lot to consider when rethinking their selection of tools after the exercise.

## 5.1 Criticism

The teams had not set up their tools or shared Skype contact details, so the challenge begun by using the already established channels, email and Facebook, to find the missing information. One of the improvement ideas was to allow 10-15 minutes of setup time before the challenge to share all the necessary contact details and test them - basically run even faster prototype on the tool usage. The internet connection quality in the exercise location was another topic for feedback, as the wireless network had some capacity issues and blind spots, which caused problems to some of the participants. On the other hand, the challenges with Internet connectivity are a part of the global collaboration in any case, and some of the interviewees even suggested adding random errors to the connection to simulate the real-life connectivity issues.

## 5.2 Development

Container challenge showed positive short-term results while the teams were selecting their remote collaboration tools, and it helped the team to avoid some potential challenges in starting their distributed work. However, as a single exercise its power and reach was limited, and the teams still encountered most of the typical issues we set out to avoid later during the class. Yet, the positive effects to the teams seemed to be significant compared to the time investment of the exercise, and the overall process of prototyping these meta level skills showed good potential for further development of Container Challenge and similar exercises to other challenging parts of the whole design process.

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# ESTABLISHING AND LEVERAGING NETWORKS IN DESIGN EDUCATION INNOVATION PROJECTS

**Nicholas SPENCER[1], Roderick WALDEN[2], Benny LEONG[3], Mark BAILEY[1] and Mersha AFTAB[1]**
[1]Northumbria University, Newcastle, UK
[2]University of Technology, Sydney, Australia
[3]Hong Kong Polytechnic University, Hong Kong

**ABSTRACT**
Project networking is the practice of obtaining needed services, ideas, or content by soliciting contributions from individuals, groups and organisations external to a project's core team. The ability to establish and leverage networks is an increasingly important component of developing open innovation practices within many industries. This research examines the strategies and tactics employed by multidisciplinary undergraduate and postgraduate students to finding, forming and utilising idea-supporting networks. Three academic institutions, Northumbria University, Hong Kong Polytechnic University and The University of Technology Sydney, brought together a multidisciplinary collection of students and academics to explore hand hygiene solutions in their respective domestic culture and a foreign culture. While each of the student teams aimed to produce design research that uncovered opportunities for social benefit and profit, the project concurrently sought to explore two research questions: 1) what approaches to establishing networks in innovation projects emerge during a globally connected educational programme and 2) what value is leveraged to support project development? This research builds on work about Open Innovation Networks focusing on idea development and reports findings about innovation enhancement and innovation suppression that emerged as a result of distributed digital design research.

*Keywords: Innovation, Networked Intelligence, Multidisciplinary, Project Networks*

## 1 INTRODUCTION

There is a growing body of work examining open innovation in business [1] and open innovation as a cultural practice. Some of this work includes: how to build innovation networks [2]; case studies identifying the innovation potential of networks to aspects of a value chain [3]; Living Labs [4]; networks that are utiliser-driven, enabler-driven, provider-driven and user-driven [5]; and networks for discontinuous innovation [6]. Network Innovation refers to innovation taking place in networks of people and organisations and is one of the goals of open innovation, which is fundamentally a self-organising model, because the open innovation network and its operation build on voluntary collaborations. One of the promises of product development that emerges from genuine connections to communities of public are innovations that have a superior match with user needs and can be up-scaled promptly to the global market [5]. It is recognised that developing successful network innovations includes three distinct and significant challenges: finding the right partners, forming relationships with them, and then building high-performing networks [6]. This study is set in the context of a technologically mediated globally distributed multidisciplinary educational project, where teams of undergraduate and postgraduate students aimed at innovating with soap to improve hand-hygiene while exploring business model implications.

## 2 THE RESEARCH CONTEXT

The primary study this paper reports on draws from a technologically mediated collaboration between three academic institutions. Two of those institutions were represented by multidisciplinary Masters programmes: MA/MSc Multidisciplinary Innovation, Northumbria University (NU) and MDes International Design and Business Management, Hong Kong Polytechnic University (HKPU). The third partner was a group of students from the Bachelor of Design (Industrial Design), University of

Technology Sydney (UTS). 58 students represented those programmes and were supported by a core team of 11 academics. The project brief asked students to investigate and understand hand-washing behaviours, routines and rituals and two regions (HKPU – Mainland China and Hong Kong, UTS – Australia and S Korea, NU – UK and Brazil) and based on insights from primary and secondary research to create innovative 'localised' solutions to fit the organizational context of a (named) multinational FMCG. The challenge included identifying an area of societal behaviour that could be modified through behaviour change and lead to improved hand hygiene habits. In order to achieve these project goals the teams were encouraged to connect with people and communities living in or connected to their project context to explore issues and solutions. The project ran over a 7-week period and progress was periodically shared to review the phases of research, insight development, ideation and final pitch. A project space was set up using Google+ accounts and pages, which exposed each team to the activities, networks and insights being established by teams in each institution.

The researchers expected that in this study the student groups would identify and establish connections with: prospective user groups after identifying a particular problem context; people in the medical profession or medical professional bodies to deepen their understanding of the implications of different hand-hygiene practices; and to develop connections and contacts with cultural knowledge of their non-domestic areas of context (South Korea, People's Republic of China and Brazil), including but not exclusively NGOs actively serving in or studying the low-income social stratum in selected regions of these nations. In order to be pragmatic, the researchers anticipated the student teams to: (a) form a shared network to help understand the situation and define the problem(s); (b) refine that network for developing ideas or solution conjectures and then; (c) access a network of expert and lead-users for testing and developing concepts. It was anticipated that this network's reach would be exercised by connecting to particular online communities or discussion groups – related to target consumers and cultures – via the known social-networking platform(s) in the Internet.

## 3 THE RESEARCH PROCESS

This research includes the planning and running of the collaborative project as this work was informed by the researchers and influenced the data collected and reported here. However, in order to answer the research questions a discrete data collection and analysis process was followed using the 'Innovating with Soap' project as its primary source. This research had five steps in its process:

(1) Network Map Production: Reflective interviews with representatives of each of the project's teams were conducted. During these interviews network maps were draw up by the interviewer in real-time. The interview consisted of guiding the participants through a reflection on their project activities, primarily chronologically. These guided reflections required the students to describe who they connected with, outside of their immediate teams, how they connected to those individuals, groups or organisations, what type of project activity those contacts feed into and the value of the connection to the project's development. This information was mapped and coded, illustrating chains of events that lead to successful or unsuccessful contacts being established and leveraged. This step involved 13 interviews with 46 project participants. 8 of the project's participants where not present during the interviews however, each team, when asked, felt that they had accurately portrayed the team's activities and network during the interview. This was confirmed by cross-referencing the information in the maps against the project's development materials, which were captured on a Google+ project page.

(2) Data Selection and Cleaning: Individual data pieces were identified and re-presented to ensure consistency in data presentation. The data presentation describes the journey to establish a contact and the value the contact represented. Data piece NU_T1_N7 (Institution_Team_Data Piece) serves as an illustration. This particular story began with the website http://www.theanswerbank.co.uk. The students searched, 'make contact with people in Brazil' and through this site identified http://www.interpals.net, which is the linking organization to establishing a network contact. Using http://www.interpals.net and a search for Brazil, eight individuals were identified, written to and invited to be involved with the project. Three of these responded positively and one became a project contact. That individual was linked to a project Facebook group and a number of Skype interviews were held where the project team sought to better understand life and culture in Brazil. This successfully contributed to the team's understanding of the project context and situation. However, the contact was not maintained and

was not invited to co-create ideas as part of the team or asked to review and feedback on ideas that were developed. Once cleaned the data piece was presented in the following manner:

Data Code: NU_T1_N7
Original search location: http://www.theanswerbank.co.uk
Search Parameter: 'make contact with people in Brazil'
Linking Organisation: http://www.interpals.net
Number of potential contacts identified and contacted: 8
Respondents: 3
Contact established: Female_24
Contact Dialogue: Facebook & Skype
Project Value: Cultural Knowledge
Solution Co-creation: No
Solution Validation/Feedback: No

(3) Data Clustering: The purpose of this step was to organise the cleaned data pieces into clusters to identify different routes to establishing project contacts. Reviewing and clustering the data pieces identified two distinct network activities: utilising existing personal and professional networks and using project content searches to establish new personal and professional relationships. This research step divided those two channels to cluster data under the following headings: Amenable Personal Networks; Networked through Friends and Family; Content Connected Friends and Family; Trusted Personal Networks; Trusted Professional Networks; Linking Organisations; Content Searches; Direct Approaches; Related Organisations; and Publishing.
(4) Cluster Analysis: Each cluster was examined to identify expected, best practice and novel approaches utilised to establish, extend and leverage the network.
(5) Data Review: A Masters project, 'Town of Colour', from the 2013 academic year completed at Northumbria University by the MA/MSc Multidisciplinary Innovation cohort was identified by that programme's academic team as exemplary for the project network that was found, formed and utilised. The project's manager, from the student cohort, was interviewed and project materials reviewed to produce a network map using the same procedures as Innovating with Soap. This data was positioned against the Innovating with Soap project data to highlight missed opportunities to find, form or utilise project networks.

## 4 DATA EXEMPLARS

The research process materialised the Innovating with Soap project network. It allowed the researchers to identify exemplar approaches to utilising existing and establishing new personal and professional connections. These exemplars are not intended to be exhaustive but are useful in illustrating the students' ability to generate value for project development by extending the reach, knowledge base and expertise of their respective team.

### 4.1 Data Exemplars, Utilising Existing Personal and Professional Connections

To utilise and extend existing personal and professional connections four approaches emerged, which were: (1) invitations to join and work with or as part of the project team offered to trusted family and colleagues, (2) direct approaches to close project content connected individuals, (3) trawling amenable online social networks, and (4) requests and offers to be networked by close and trusted colleagues, friends and family to content relevant individuals, either by a direct requests or by taking opportunities to expose project development to interested parties (anyone who would listen).

Exemplars of utilising existing personal and professional connections were:

(1) Invitations to join the project team (a) a team member's boyfriend, who has 10 years experience in product development, joined the major weekly project development sessions and made contributions across the full range of project activities; (b) a team member's niece and family (who was representative of the solution's target user) were filmed and involved in prototype testing and reviews; and (c) a team member's mother and wife were involved in scenario development after producing project specific photo-diaries.
(2) Direct approaches to project content connected individuals (a) a team member's friend was a work supervisor in a shoe factory and they helped gain access to tour the factory and conduct interviews with the female workers (which was this team's intended user group); (b) a number of the teams approached an associated visiting Professor with particular expertise in design,

innovation and soap to supply specific knowledge about the project's key technology; and (c) a team member's aunt, a nursing director in the UK's NHS, was contacted and willing to help but was never used.

(3) Trawling amenable online social networks (a) Project questions and challenges were posted on team members' Facebook wall, those who responded were then invited to join a Project Facebook group which discussed and reviewed problem descriptions and solution proposals; and (b) surveys were produced and sent out across 'friends' via social media (Facebook and QQ), while response numbers were generally high the results were not particularly directive for the project's development, however, at its best the responses allowed insightful or helpful individuals to be identified occasionally leading to focus group invitations/activities.

(4) Requests and offers to be networked (a) a team member's father had a friend who knew a local government official, this individual helped the team gain access to and visit a low-income community in PRC which led to the team conducting 20 interviews and a number of day-in-the-life photo diaries; (b) a programme tutor identified a Brazilian national on an associated design programme, positive contact was establish but the individual was never engaged in the project; (c) a programme tutor identified a PhD student working in-field in a region associated with low-income (and assumed low hand-hygiene), this led to interviews with the doctoral student and their supervising Professor, which then led to the identification of project related NGOs, these NGOs were however never contacted; and (d) one team produced a project blog to attract interested persons to contact and contribute to the project.

### 4.2 Data Exemplars, Forming New Personal and Professional Connections

Three approaches emerged for finding and forming project specific connections not associated with any existing personal or professional contacts, these were: (1) through linking organizations, (2) through digital content searches, and (3) by direct physical encounters.

Exemplars of establishing new personal and professional connections were:

(1) Using linking organizations (a) through, http://www.interpals.net, an individual based in Brazil was connected to, interviewed and invited into a project Facebook group, the contact was not maintained beyond the initial interviews; (b) search results from, http://ilas.sas.ac.uk, led to 7 UK academics with research expertise in Brazil, one of which referred the team to his wife who was an expert in the project area of interest and whom agree and contributed to context understanding; and (c) the Brazilian Embassy in the UK was contacted and a list of Brazilian societies based in the UK and NGOs working in Brazil were provided, non of those were pursued.

(2) Using digital content searches (a) searching 'poverty in Brazil' returned a number of interesting and useful blogs, the sites' materials were used but blog authors never contacted (b) searching 'favela tours' returned an article on Rochina and a DJ school for children. Zenhzenhino, the DJ, was then found on YouTube, emailed, contacted, interviewed and he subsequently provided two further contacts for hygiene expertise in Rochina, who were not successfully connected to.

(3) Using direct physical encounters (a) to find and form new connections with female workers in PRC a team booked sessions with a massage therapist, interviews were conducted during the session, a bond established which led to the team's ideas being reviewed by these contacts via text message (b) deliberate and regular visits to a local restaurant resulted in friendly conversation with the waiting staff, this led to a series of interviews outside of working hours (c) visited a low-income community in HK and conducted on-street interviews, non of these resulted in any further contact.

## 5 RESEARCH FINDINGS

With consideration to previous Master level projects the network established by the students during 'Innovating with Soap' seems typical. The results of this study, examining the network's creation and utility, highlight both expected and novel behaviours and missed opportunities which raise interesting questions about the support and training students receive for project network management. The research findings can be considered within 5 areas, these are: Expected Network behaviours, Best Practice Network Behaviours, Novel Network Behaviours, Poor Network Behaviours, and Missed Opportunities to Leverage Project Networks.

(1) Expected Network behaviours - Existing personal networks are easiest to access and were most readily used. Anticipated and expected approaches to utilising and extending existing personal and professional connections were: using trusted family, friends and colleagues for discrete project activities; directly approaching individuals who have some knowledge relevant or connection to the project area or asking trusted connections for introductions to people they know; and trawling online social networks with blanket surveys. Evidence suggested that most of the project contacts established were used to fulfil an immediate knowledge gap to help understand the project situation and problem.

(2) Best Practice Network Behaviours - Teams that extended the involvement of individuals in the project exemplified best practice; teams that identified and involved relevant contacts for strings of activities as opposed to isolated activities: i.e. when a nephew and his parents were used in video production but also involved in product testing and evaluation. Some of the teams made valuable new connections through content searches and linking organisations that involved multiple steps and many communications to arrive to and connect with a relevant individual or team. As a result teams benefited from expertise and cultural knowledge not immediately available. The students valued this knowledge and the excitement of the hunt.

(3) Novel Network Behaviours - Teams that included family members regularly into project activities evidenced novelty in this area. Using online surveys to identify individuals interested and able to contribute to the project to form focus groups was also a novel approach. Personal and professionally trusted connections appear to ensure engagement in activities, as involvement is simply another aspect of a deep ongoing relationship.

(4) Poor Network Behaviours - Finding and forming new content specific relationships is difficult. For the students there was no obvious negative consequence to letting the lead go or maintaining the connection. The data showed that if instant gratification is not received or potential benefits not recognised then the effort to establish or maintain the connection outweighed its perceived value. Often contact was established but not maintained as the perception was that the contact was not useful for the most immediate tasks or knowledge gaps. Developing trust within the network is critical to increasing the opportunities to set-up project networks to co-develop, verify and test ideas. Trust is difficult to develop during projects with short time-spans particularly when communication is digitally enabled. None of the student teams had an approach for developing trust within their project network and none of the student teams discussed debriefing their contacts about the project's outcome or thanking them for their involvement.

(5) Missed Opportunities to Leverage Project Networks - In this project there appeared to be a lack of confidence in co-creation strategies, which was a significant missed opportunity. Establishing and managing a co-creative network was (as we discovered) always going to be difficult when working so remotely from each institution and for some project teams so remotely from their target culture. Due to the pace of the project many groups reverted to a more traditional user-centred approach relying on the core team's skills and knowledge as opposed to the collective expertise of a project network. While some aspects of co-creative activity did emerge with contacts from individuals' personal networks and with new project specific contacts it was surprising that the students from each of the three institutions did not use each other beyond the formal sharing sessions. There were opportunities to have greater dialogue and review of ongoing progress using the Google+ pages and other social media being used. Although difficult there were opportunities to use the creative resource by organizing cross-institutional co-creative sessions around linking hygiene themes that span cultural differences existing within the project. Rather than viewing each other as collectives working on the same project institutional competitive behaviours were observed. Opportunities to utilise expert knowledge by connecting to extensive networks of related NGOs were not taken and opportunities to connect to lead-users were missed; e.g., in this particular project there was the chance to connect with bloggers, which was missed.

Questions resulting from this study are: can co-creation strategies be effectively implemented when the network is internationally distributed and mediated through digital media; what pre-project planning is required to ensure networking opportunities and efforts match the project's scope, content and timeframe; what supportive tools could be developed to help student teams effectively manage, ensure ethical standards are adhered to and dissolve project networks; what teaching about developing and utilising project networks do design and innovation students require to help them balance expending effort versus generating value?

## 6 CONCLUSIONS AND FURTHER WORK

Students aiming at innovation are very good, entrepreneurial at times, in the use of personal networks and in finding relevant and novel content specific connections. Students would appear to benefit from greater guidance and supporting tools, not only in how to best maintain and manage their project network toward and during co-creation, but also guidance in how to dissolve and disassemble the network during and after a project's completion. The evidence of this study suggests that students working on design and innovation-focused projects think of project networking as supportive of discrete design process activities. In this study that mindset resulted in poor network management and many missed opportunities to extend the value and input of connections once established. This work suggests that there is value in thinking about project networks as entities and outcomes in their own right with value not just for the immediate project but also, potentially, for ongoing creative work. This change of emphasis might lead to more effective searches to identify 'the right people and organisations' not solely to fulfil an immediate knowledge gap or task need but to support project development across the full spectrum of activities (and potentially across future creative projects). Extending this study research is planned involving a combination of product development and digital media SMEs in the UK and academic teams of students and staff. The work will explore the benefits and opportunities to enhance commercial advantage in product development through access to and use of the 'Crowd'. The project plans to co-create through open networks a digital platform to facilitate crowd-sourced and funded product development.

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# HOMECARE FUTURE SCENARIO DEVELOPMENT BY STUDENTS IN A MULTIDISCIPLINARY SETTING

**Margot STILMA[1], Fenne VERHOEVEN[2] and Karin VAN BEURDEN[1]**
[1]Research Centre for Design & Technology/ Research group Industrial Design, Saxion University of Applied Sciences, the Netherlands
[2] Research Centre for Technology & Innovation/ Research group Co-design, University of Applied Sciences Utrecht, the Netherlands

**ABSTRACT**
The development and implementation of a 'future scenario development-method', is described in this paper. The scenarios should inspire designers to create products that fit the society 10 to 20 years from now. The future scenario development-method enabled both health care and product design-students to work together at different locations. The method consists of four steps: 1. project demarcation, 2. driver analysis, 3. scenario development, and 4. scenario writing. The applied method appeared helpful in communication between the different disciplines and their mutual understanding during the project.

*Keywords: Interdisciplinary, design, health care, future, scenario, caregiver, homecare*

## 1 INTRODUCTION

This paper describes the insights generated from a project on technology and health care in which students from multiple disciplines cooperated. The project was part of a larger project funded by the Dutch government. The larger project was called "Designing for home care providers" and focused on how to design smart and usable products for caregivers in the home setting. Whereas in the development of home care innovations, the focus is often put on patients and their experiences, this project took another angle. Since caregivers are the major user group of home care innovations, rather than patients, the focus was on the professional home care providers as well as the informal care givers (family members, friends, neighbours et cetera providing at least eight hours of care a week), as the main target group. The overall project lasted two years (2011- 2013) and had several sub-projects.

One of the sub-projects of this larger project concerned future scenarios to create insight into home care design opportunities. The project took place at the Research Centre for Design & Technology of Saxion University of Applied Sciences in Enschede (the Netherlands), in cooperation with the research group Technology, Care & Wellbeing of the same university. Simultaneously, researchers from the Research Centre for Technology & Innovation of University of Applied Sciences Utrecht (UUAS) (research group Co-design), also in the Netherlands, were involved. In Enschede, two nursing-students of Saxion University and one student from Industrial Design Engineering from the University of Twente participated. In Utrecht, two students in Management in Healthcare and one Product Design & Engineering student (all from UUAS) participated. Thus, the future scenario project became a collaboration of three researchers (among them were the authors of this paper) from three research centres and six students from different healthcare and product design disciplines, who worked simultaneously on the project.

The aim of this paper is twofold. First, the development, implementation and reflection of the future scenario development are described. Second, it is explained how the method enabled the students from different disciplines to effectively and efficiently communicate.

### 1.1 Working in a very multidisciplinary team

Although multidisciplinary student team cooperation is common both at Saxion and UUAS, the diversity of backgrounds in this team was more diverse than usual. Consider that healthcare students are mostly trained to focus on current healthcare situations, whereas product design students are predominantly trained to concentrate on future product development. Elaborating on the complexity of the team, Utrecht and Enschede are located 140 kilometres from each other, which impeded

frequent face-to-face-meetings. This situation made the project challenging. An approach was needed in which all participants could work together on the same project, in a way that was understandable and workable for each.
Therefore, a future scenario-method was developed and implemented which will be described in the next chapter. Regular meetings were planned in line with the used method. In addition, there was contact during happenings organized as part of the overall project, such as consortia meetings or a creative educational day on the subject. When needed, the students and supervising researchers had contact via Skype and shared a common Dropbox in which relevant documents were recorded.

## 2 DERIVATION AND DESCRIPTION OF FUTURE SCENARIO METHOD

The used method was based on different methods and models. The process of developing future scenario's was derived from the method used in the minor "Futures: Imaging Tomorrow's World", taught at the University of Twente [2]. One of the participating students in this project, participated in this minor in 2012 and incorporated the generated knowledge into the project. This started with describing the model in a document to develop strategic future scenarios in the following seven steps [3]: 1. Focal issues, 2. Actor/factor analysis, 3. Uncertainty/ Significance matrix, 4. Scenario matrices, 5. Scenario plots, 6. Scenarios, and 7. Use of scenarios for strategic developments for tomorrow's world.
Although the model is very clear, it concentrates on strategic developments as outcome, whereas the focus needed to be on product design opportunities.
Extra input on the model was derived from the method used in the research project 'Safety at Work', focusing on Technology and Safety [4], another research project performed at Saxion University. Here the PESTEL model [5] (Political, Economic, Social-cultural, Technological, Environmental and Legal-analysis) is used to categorize future developments and predicting factors for future developments. Since multiple many factors on several levels together determine what the future will look like, a model is essential for clarifying and structuring these macro-economic factors and developments. However, the PESTEL model limited the health care oriented research, as none of the drivers considered demographic information. As there was good experience using the DESTEP-model [6] in earlier projects (particularly the health care students were already familiar with this model), the DESTEP-model was incorporated as part of the Actor/ Factor Analysis. DESTEP categorizes the Demographic, Economic, Social-cultural, Technological, Ecological and Political drivers found in literature, expert interviews and other relevant sources. Moreover, the future scenario expert who participated in a workshop during the organized creative day, used DESTEP as part of her approach.
Another interesting element from the 'Safety at Work-project' was the use of roadmaps, to map the future developments on a time line. This would make it more clear when certain developments would take place simultaneously.
The relevant aspects of all aforementioned approaches (thus 1. Seven-step-model, 2. Product design focus, 3. DESTEP-model, 4. Roadmap) were fitted into phases of the project. The reviewing of results per step were matched to planned meetings with all participants. Each step represented about a month of work. In the following paragraphs, these steps and its execution are explained in more detail.

### 2.1 Step 1: Project Demarcation

This step concerns determining the approach and goals of the project. This results in a 'plan of approach'-document, which is needed for the students' educational programs. It relates to the first step of the method used in the minor "Futures: Imaging Tomorrow's World" [2], where in this step, the focal issues, the assignment, the client, and the project goal(s) are described.

#### *2.1.1 Execution of step 1: project focus for Future scenario-development for homecare*

The common project focus was that at the end of the project, future home care scenarios had to be created. Scenarios that provide designers a guideline to develop new products and services for the homecare setting, taking into account the viewpoint from care providers rather than patients. Therefore, the results of this project had to be presented in such a way that they guide and/or inspire product designers.
Focus of the project was on homecare in the near future and the possible developments of technologies for product development. In order to develop realistic scenarios rather than fantasy-ideas, it was decided to focus on two moments in the future: in 2015, and in 2020. This close range was chosen

because of the limited knowledge of possible applicable technologies beyond this time range. Homecare is care provided by both professional caregivers, as well as by informal caregivers, such as care provided by family and friends at home. The type and amount of care needed depends on the patient's disease.
Working with two groups of researchers and students at two geographically different locations, created an extra opportunity. The situation was utilized by studying parallel two different diseases representing two kinds of abilities or restrictions. Therefore, researchers and students from Utrecht focused on chronic heart failure, whereas the Enschede-students and researchers concentrated on dementia. Both diseases are among the most common chronic diseases with an increasing incidence in the near future. We identified these diseases because of their diverse character. Chronic heart failure implies physical limitations for the patient, whereas dementia entails cognitive limitations.

#### 2.1.2 Group dynamics step 1

In order to enable the students and researchers to successfully and simultaneously work on the same project on two locations, we let them stick to the same format of describing project goals. By comparing and streamlining the results of both locations, the project gained more in-depth knowledge.

### 2.2 Step 2: Driver analysis

After project demarcation, the actual execution of the project started by analyzing the drivers (determinants of future developments). This step relates to the second step of the method used in the minor "Futures: Imaging Tomorrow's World" [2], where major part of the work involves an extensive literature study to detect all relevant actors and factors that play a role in the future. In an Actor-Factor analysis, the relevant future developments and related groups of people and organisations are mapped.
The use of the DESTEP model particularly helped to incorporate the health care-related developments, and divides the future developments in Demographic, Economic, Social/cultural, Technological, Ecological and Political-factors. The collected data was reflected with experts.

#### 2.2.1 Execution of step 2: overview of the driver analysis

We used a systematic literature research to gain an overview of the drivers, which resulted in mapped future developments per DESTEP-category. The results were reflected and validated in structured interviews with experts and in structured focus panels with experts. These results were again exchanged and discussed during the multidiscipline project meetings. Continuing the categorical DESTEP analysis, the results were extracted and placed on a timeline, comparing the current situation with future developments. The technological developments were placed on a time line in more detail (see *Figure 1*). This helped in creating product ideas in a later phase. A summary from the complete results of the DESTEP-analysis, which are reported in the student reports [3] [1] [7], is given below:

- Demographically, there appeared to be an ageing population who will have a longer vital life together with a relatively decreasing amount of caregivers.
- Economically, the government care budget will be decreasing and as a consequence, homecare demand will increase. Risk of this increasing demand is overworked informal home caregivers.
- Social-culturally, there exists the risk of increasing loneliness among informal caregivers due to their (time) consuming care responsibilities.
- Technologically, whereas medical and technological solutions may decrease contact moments with healthcare providers, the medical and technological solutions may contribute to vital living, and create more freedom and social interaction on the other side.
- Ecologically, more attention will rise for safe living environments, such as privacy values in cases of homecare and distant home monitoring, or safety issues like prevention of accidents in the house, or for protection against easy targets for crime.
- Politically seen, the focus will be on self-regulation and prevention of diseases. New focus will be on healthcare policies due to the decentralizing healthcare portfolio to local governments.

#### 2.2.2 Group dynamics step 2

The results of the DESTEP analysis were shared and reflected among the two groups of researchers at Saxion and UUAS in several phases, from first DESTEP results to the validations in interview and focus panel discussions. The DESTEP model helped in structuring the results which made it easier to compare the drivers that were gathered by both groups. Reflecting the parallel approaches on the different diseases helped in discussing the results and creating shared understanding. Moreover, discussing the developments helped in getting more feeling for the possible future situations.

## 2.3 Step 3. Scenario development

The scenario development process concerns the translation from the Actor-Factor-analysis to input for scenarios. In this step, more understanding is created on the wide range of drivers. During this scenario development process, interviews and an expert panel were used again as reflection and validation.

The most relevant drivers were discussed on and placed on axes, mapping the uncertainty of drivers to happen to the rate of their importance (see Figure 2). The (un)certainty and importance of future developments form the basis of scenario matrices and plots. It helped in determining the axes to be placed in the strategic field, where the scenario scan could be plotted. The locations of the plots in the matrix determines the different perspectives on the future.

### *2.3.1 Execution of step 3: from drivers to places where scenario plots can be placed*

Based on the mappings, such as shown in *Figure **2***, we concluded that for the strategic field of future of home care, the amount of social contacts (Social-culturally), the available financial means (Economically) and the amount of technological developments (Technological) were particularly relevant. Moreover, these categories were most commonly mentioned in the feedback gained from experts in the field. After analysing each quadrant, four plots were chosen to develop scenarios in (see Figure 3).

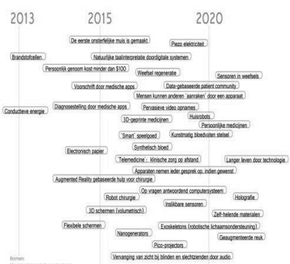


*Figure 1. from Timeline of technological developments [3]*

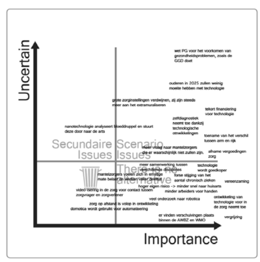


*Figure 2. Uncertain-Importance matrix, a mapping of all relevant drivers [3]*

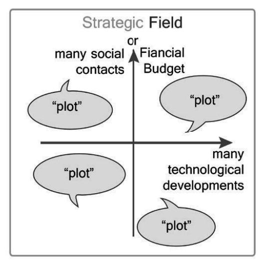


*Figure 3. Strategic field with metaphoric scenario description for possible scenario plots*

### *2.3.2 Group dynamics step 3*

Discussing together which drivers had most impact and determining which axes were going to be used for the scenario matrix, brought the group closer together. The discussion gave all disciplines the opportunity to understand the different interpretations due to various backgrounds. It helped to regain the common focus on the implementation of the future scenario development. Especially this step needs extra attention for discussions and integration of different developments.

## 2.4 Step 4. Scenario writing and creating design opportunities for product designers

After plotting the future developments and the determination of the strategic field, the future scenarios could be written. The scenario development started with creating a macro view on the economy, which was further developed to a description of the daily life, containing dilemmas and possible design solutions. The daily life-format helped in imaging the future situation: it is easier to connect and improvise from a daily setting than from a rather abstract text.

In *Figure **4***, a visual is given of macro scenarios placed in scenario matrices. Specific axe determine the focus of the macro scenario. For each macro scenario, first the dilemmas and opportunities for product development are determined. Based on these macro scenario's first ideas for possible product development directions were generated.

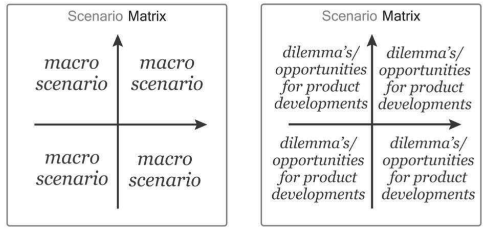


*Figure 4. Mapping scenarios and design opportunities*

#### 2.4.1 Execution of step 4: from macro scenario to daily life descriptions using personas

The way of presenting the future scenarios of homecare situations was discussed with experts within the project. An overview was made including the macro scenario and the daily life description using personas. The following figure, depicts a short overview of a scenario. Next to textual descriptions, photographs of personas and graphical or sketches of design ideas were explicitly used.

The macro scenario described the situation of the society, e.g. socially, people are going to seek contact in their neighbourhood in case of asking for and/or providing care. An overview of a daily life scenario is given in *Figure **5***.

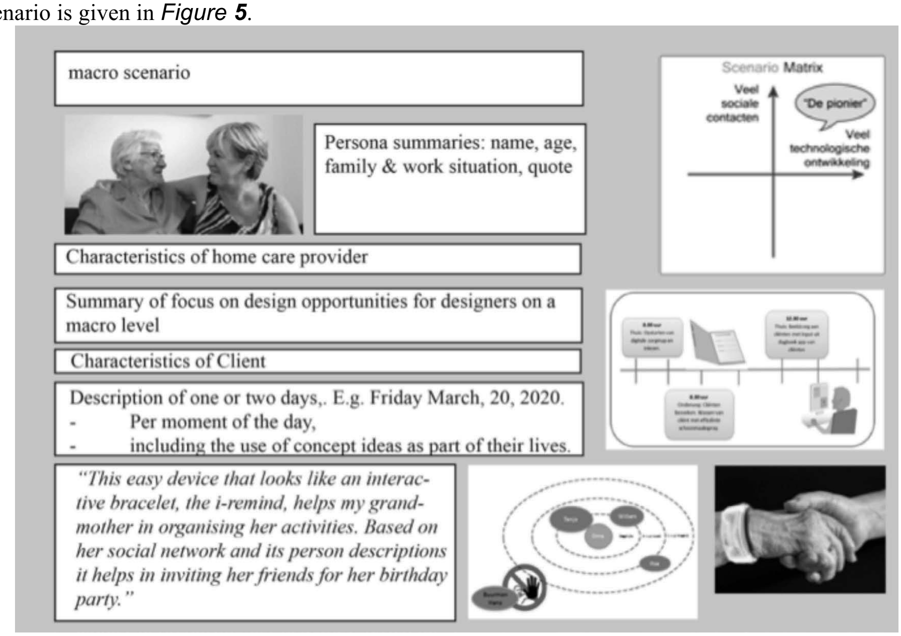


*Figure 5. Elements of daily life scenario*

#### 2.4.2 Group dynamics step 4

The setup of the daily life scenario helped in the focus of the group and getting the input to a good level. ´Knowing´ the personas also helped the students to enrich the possible design solutions.

## 3 EVALUATION AND CONCLUSION OF THE WAY THE MODEL WORKED

The future scenario development-method entailed three major benefits. First, it enabled researchers and students from different disciplines to efficiently and effectively communicate and work together. Second, connecting the different disciplines challenged the students to cross their educational borders. Third, it generated useful and tangible scenarios for the home care setting in the future that should inspire designers to create innovations. Each of these benefits will be elaborated on in the following.

First, by formulating the project goal together and keeping that in mind during the entire project, shared understanding was realized among students from different backgrounds. Moreover, the scenario development-method consisted of specific steps and tools that enabled both technical as well as health care-students to perform the project easily and effectively. Since the method comprises formats for matrices and scenarios, it was clear for students what the output of each phase had to be. Providing students with clear formats prevents endless discussions on how to present collected data. For instance, the DESTEP model helped in structuring and comparing the drivers. Also, the matrices and scenarios stimulated common and fruitful discussions and helped to focus discussions.
Second, the interaction of the group and the guidance of the method helped students in crossing the educational backgrounds and broaden their view. They challenged each other to think out of their educational way of thinking. They mentioned themselves the value of this project in that context.
Third, the creation of the future scenarios: the rigid format of the different steps and the formats for matrices and scenarios not only enabled efficient and effective cooperation between disciplines; it also generated useful and inspiring scenarios for the home care setting in 2015 and 2020. The scenarios were presented to a group of professional product designers and they all perceived the scenarios as inspiring and useful.
The method, of course, also implied several drawbacks. Regarding the students' different backgrounds, it appeared that despite the formats within which the students had to work, they perceived it difficult to have empathy for the other discipline. Students kept close to their way of thinking and acting from their own discipline. For instance, health care-students had more difficulty in generating product design ideas for the scenarios, probably since they are more used to work according to a strict protocol rather than free thinking, which is more usual for design-students. This might also be due to the required content of the student's work for their education.

## 4 DISCUSSION AND POSSIBLE ADJUSTMENTS TO THE METHOD

Due to the used method with the constant multidisciplinary interaction during the project, interesting results were achieved. Attention should be paid to create empathy for each other's discipline, rather than rigid thinking from one's own background. Taking more time for the elements where cross-functional thinking is needed, this model will gain more power and better results are expected. To consolidate the method, we suggest special workshops using creative thinking theories, when mapping the drivers on the Uncertain-Importance matrix in step two, and when determining design opportunities in step three. As mentioned before, the used method facilitated shared understanding between students from different disciplines and generated useful future scenarios for the home care setting.

## 5 THANK YOU

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Chapter 12

# USING TECHNICAL TOOLS IN DESIGN

# EDUCATING DESIGNERS FROM GENERATION Y – CHALLENGES AND ALTERNATIVES

**Miroslava PETROVA**
University of Forestry – Sofia (Bulgaria), Department of Interior and Furniture Design

**ABSTRACT**
The paper discusses the learner characteristics and the corresponding teaching strategies that can be applied to the education of Generation Y (Gen Y) – the cohort born between the early 1980s and the early 2000s. Experienced with digital technology from their early childhood and exposed to tremendous amount of information which can be instantly accessed, Gen Y students are highly demanding of their education. This poses the challenge of updating and adapting the teaching to their changing learning needs and expectations.
Based on the findings of a survey on the specific profile of our students concerning their technological background, interests and preferences, we have come to the conclusion that lectures and seminars do not provide the optimal learning environment. We were motivated to propose a series of extra-curricular activities built on the teaching material of the disciplines Form-formation and Theory of composition. The paper reports our teaching experience of several systematically selected educational formats brought together under the name "Student scientific-educational forums". They include research papers, debates, conferences, creative workshops and virtual exhibitions. By introducing these activities we aim to enhance learning in the two disciplines, to engage students actively in the educational process, to enable them to discover by themselves what they need to know and to link the theoretical studies with practical design problems.
In conclusion we evaluate the quality and effectiveness of these new teaching strategies. Furthermore we discuss how students' academic development is affected and how the implementation of the proposed activities results in more successful learning.

*Keywords: Generation Y, experiential learning, student-centred education, interactive education*

## 1 INTRODUCTION

Debate and research on the impact of technology on educational process has become increasingly relevant in recent years. Born in an age of technological breakthroughs today's students are accustomed to using computers and cell phones from their early childhood. Technology is considered much more than a tool for the generation "born with a chip" [1]. It is so deeply embedded in their lives that it had a profound effect on their behaviour, attitude and lifestyle. They are ambitious, experiential and active learners, who communicate predominantly through instant messaging and social networking, prefer working in teams and enjoy multitasking. Generation Y [2], Millennials [3], Net Generation [4], Trophy Kids [5], Dot.Com Generation [6], Digital Natives [7] are the most popular names given to the generation that shares these inherent traits. In this paper we will use the term Generation Y (Gen Y) and will discuss the learner characteristics of the cohort and the corresponding teaching strategies that can be applied to design education.
Technology not only shapes the way students communicate and collaborate with each other but also redefines the context of contemporary education. As a result of the established new models of information access and sharing, Gen Y students are not satisfied with the traditional methods of teaching and become more demanding of their lecturers and the technological tools they use in class. They prefer a more student-centred learning style where knowledge is acquired through experience instead of passive receiving of information. Offering various opportunities enabling them to participate actively in the educational process, take the initiative and have choice is also highly appreciated because students feel they have the responsibility for their own learning. In order to respond adequately to the changed needs and expectations of today's students a conceptual transformation of the educational system is required [8]. It should reflect the technological shifts of the

global society and support the information-age learners. When the program is tailored to their specific characteristics, students' motivation is increased and this leads to improvement of their academic achievement and overall enhancement of the effectiveness of the education.

## 2 IMPLICATIONS FOR STUDENTS' LEARNER CHARACTERISTICS

Studying the defining characteristics of Gen Y that distinguish them from other generations is a key factor in understanding their attitude towards education and hence determining the most appropriate teaching strategies. Gen Y have grown up in a world of rapid technological advances affecting the way they learn, their approach to knowledge acquisition and the forms of interaction between themselves, with lecturers and with the training resources. As a result of their techno-dependency and the fact that they are accustomed to using computers and internet to perform any given task, Gen Y has formed a set of unique characteristics and competences which predetermine their individual learning style. The representatives of the cohort are described as special, sheltered, confident, conventional, team-oriented, achieving and pressured [3], seeking for freedom, loving to customize and scrutinize, looking for integrity and openness, appreciating entertainment, having need for speed, being innovative and collaborative [4]. In accordance with these characteristics Gen Y students choose active and engaged learning experiences within interactive environments as the most appropriate and meaningful learning strategies for them. They learn better by doing and through social interaction [9, 10], prefer to learn in their own time and on their own terms, appreciate structured activities that permit creativity, want to be involved with 'real life' issues, enjoy using technology [11] and believe they are efficient multi-taskers [3, 4, 9, 10].

### 2.1 Survey on students' computer and internet use

Though extensive research has been made on Gen Y characteristics, needs and values, at the beginning of 2011/1012 and 2012/2013 academic years we conducted our own survey on the specific profile of our students concerning their technological background, specific interests and preferences. We used the open source online survey Lime Survey (www.limesurvey.org) to program our questionnaire through which we wanted to get a more detailed understanding of the way they use computers and internet and how they apply it for educational purposes. All sixty-one surveyed students own a desktop computer and have constant access to internet. 98% reported they have a laptop as well and 69% are connected twenty-four hours through smartphones or tablets. Most of the students began using computers between the ages of 10 and 12 while only five of them started after the age of 15. This means that when they enrolled at the university they have gained experience in computer use and the survey confirms this fact as all respondents think they are adept users who are proficient in various online activities, word processing and at least one CAD software.

More than half of the students (58%) spend between three and six hours a day on the internet and one third (26%) spend an average of over six hours a day. When asked to rank what they use internet for, the survey shows that the most common use is for social networking (placed on first place by 61%). Among the secondly placed are: for doing schoolwork (35%), for reading news (22%) and listening to music (22%). Only 17% said they use internet primarily for exam preparation and other academic research. In addition, to a question regarding multitasking 96% of the students confirmed they perform a number of tasks simultaneously. These results show that our students combine learning with pleasure since they use internet as a source for communication and entertainment but also as an instrument for research and learning. We also asked the question "How do you prepare for exams" and were surprised to find that 82% prepare primarily reading lecture materials. Using search engines to find the relevant information is placed on the second position by 25% and on the third position by 40%, while only 18% indicated they browse the web first of all. Next in order come reading textbooks with 65% of the students ranking it on the second place and reading wikipedia with 5%. We surmise that a possible explanation of these results is that students choose this traditional preparation to make sure they would respond more precisely to lecturers' requirements. At the same time we asked how they receive information about the latest in the sphere of design and 92% responded they read design blogs and unfortunately only 8% think the information they get at the university is topical enough.

Regarding the most popular online activity where students spend the largest amount of their time – social interaction, Facebook turned out to be the most preferred platform with 100% of the students having a profile. Next in popularity rank Pinterest (used by 30%), LinkedIn and Instagram (both used by 22%). The vast majority of students (56%) reported logging in at least three times a day and only

12% log only once or twice a day. It is evident that social networking is very important for Gen Y students and we wanted to understand whether they use this form of communication with their lecturers. Only 18% answered positively to this question and another 78% stated they have contacted lecturers via e-mail. Among the reasons were indicated issues related to the homework assignments given at the seminars (72%), clarifying questions related to the lectures (22%) and issues regarding the schedule (13%). At the end of the survey we asked students to describe in a free text their expectations of education and among the most common answers were: training including the most topical design issues, providing opportunity to control their own learning, effective information and knowledge communication through the use of modern technology, acquiring relevant knowledge that will help them in their future design profession, education including more collaborative work.

### 2.2 Analysis of the survey results and conclusions

The results of the survey unambiguously confirmed that for Gen Y students technology is more than a tool. It is an inseparable part of their lives, engaging their attention and helping them to understand and experience the world. We found that they are very active in using technology to network and socialize but at the same time do not take full advantage of their technological skills for educational purposes. We wanted to change this by offering a more interactive teaching strategy totally reshaping the existing traditional learning experience. Gathering the most relevant information about our students regarding their technological use and preferences was very important step in the process of curriculum design because in this way we could adapt the proposed activities to their specific requirements and interests. We aimed to focus on the following knowledge and skills: to foster critical thinking skills, to stimulate students to express and communicate their ideas clearly, to develop skills to analyze and criticize, to improve their thesis argumentation and public speaking behaviour, to enhance independent learning, to stimulate creative participation. Our belief is that through providing different opportunities for student initiative and personal expression, we can respond more adequately to the generational characteristics, motivate students, enable them to develop their potential and enhance their overall learning experience.

## 3 EXTRACURICULLAR ACTIVITIES IN THE TEACHING OF FORM FORMATION AND THEORY OF COMPOSITION

After we processed the results of the survey we set the goal to update the education of the two disciplines we teach – Form formation and Theory of composition. Objectives of the courses and the applied educational methods are explained in detail by Zheleva-Martins [12, 13]. Implementing modern interactive approaches into the curriculum is an important step towards establishing a student-centred learning process fully consistent with Gen Y characteristics. Unlike conventional learning where students are passive recipients of information and rarely participate in the development of the curricula, student-centred learning is flexible, fosters collaboration and supports students' independence in controlling their own learning. Within this approach learning is more meaningful for the students and they become more aware of the skills, knowledge and competences they will acquire during their education. Next are presented examples of the integration of several systematically selected educational formats brought together under the name "Student scientific-educational forums" which were developed to complement lectures and seminar classes. In general they include research papers, debates, conferences, creative workshops and virtual exhibitions. By introducing these activities we intend to enhance learning in the two disciplines, to engage students actively in the educational process, to enable them to discover by themselves what they need to know and to link the theoretical studies with practical design problems.

### 3.1 Educational-scientific conference

The first initiative of the series was held in the winter semester of 2011/2012. This was an educational-scientific conference on the theme *"Application of Gestalt Principles in Design"*. During this semester students studied Theory of composition and the conference aimed to expand their knowledge on the topic of gestalt principles and their creative interpretation in design compositions. Lectures introduced students to Gestalt psychology's main ideas, principles and laws but the limited time of the classes did not allow deeper theoretical research and further exploration of their practical application in the design sphere. We proposed a number of topics within the main theme of the conference but we were open to suggestions from our students as well. They were given complete freedom to choose the topic, the type of presentation and the way of approaching the problem. Students responded very eagerly to this first of its kind initiative in our university as almost half of them were willing to participate. The conference proved to be an excellent platform for both self-training and collaborative work. Each participant had the opportunity to immerse thoroughly in the selected topic and by working on his own to construct his knowledge of composition and subsequently to share it with his fellow students and lecturers. Our role as educators was to guide them through the research process in preparation of the papers and posters for the event. To facilitate coordination we created a facebook page of the courses (facebook.com/pages/Formoobrazuvane) where students could express their opinion and ideas, ask questions and share relevant information. This form of communication was very successful and later on we began using the page for all types of announcements and discussions regarding classes.

Summarizing the results of the conference we can conclude that it went brilliantly and generated a number of useful outcomes for the students. Besides the developed analytical, argumentative, interpretative and presentation skills, participating students were given an excellent grade as a bonus and those who had managed successfully with the assignments and current control during the semester were exempted from the exam. Furthermore, they were awarded certificates, giving them the opportunity to compete for European scholarships. The rest of the students who did not prepare papers and posters were not just passive listeners but participated actively in the discussions following each presentation. They showed great interest in the work of their colleagues, asked them many questions and appreciated highly their efforts. At the end many of them expressed the opinion that they have learned a lot of interesting and useful things and that they enjoyed the event. For the benefit of the students of the next classes we decided to publish a CD with the conference materials [14]. The CD was issued in 2012 and opened a series of educational materials titled "Student Scientific-Educational Forums". This form of student co-participation combining the individual efforts of the participants in the conference is a logical conclusion of the event, producing a valuable collective outcome written by students for students.

### 3.2 Student debate

The debate we organized in the summer semester of 2011/2012 was another initiative aiming to increase students' involvement in the educational process. It was based on the teaching material of the discipline Form formation but the chosen theme *"Form Formation between Chaos and Order"* threw bridges to the latest advances of various fields of the scientific knowledge related to the subject. The main objective was not so much to distinguish a winner defending one or the other thesis but to go deep in the essence of the form formation principles and to see them as a dynamic dialectical opposition. We wanted to mobilize students to participate actively in the acquisition of their own knowledge, to become confident in building strategies for defending a thesis, to develop ability to analyze controversial issues, to construct and refute arguments. The debate was focusing on the development of critical thinking skills through research, reasoning, interpretation and evaluation of the supportive arguments, solving complex problems for a limited time and finally communicating effectively opinions and conclusions to the audience.

This form of experiential education promoted learning through social interaction within each group of students but also enabled the most enterprising among them to take leadership roles and to guide their teams towards taking the right decisions. To distinguish the students who were most persuasive at the end of the debate we organized voting. Those who received the greatest number of votes were awarded certificates and again had the opportunity to be exempted from the exam. Organizing and performing the debate was a great challenge both for the lecturers and the students but the attained outcomes consisting in increasing the critical thinking skills and enhancing collaborative learning were worth the efforts. Students showed eagerness to participate and estimated highly the usefulness of the debates for gaining knowledge of the discipline in a more interesting and engaging way.

### 3.3 Extracurricular activities in 2012/2013 academic year

Following the success of the events organized in 2011/2012, the next academic years we continued to include analogous extracurricular activities in the teaching. These were respectively: abstract readings on the theme *"Semiotics and Design"* (2012/2013 winter semester), workshop *"Form Formation Inspired by Nature"* (2012/2013 summer semester) and video marathon *"Composition and Style"* (2013/2014 winter semester). Each of these events was created with the objective to relate knowledge acquired in the lecture classes with up-to-date developments in modern sciences, considering the educational needs of our students. We can summarize that conducting such extracurricular activities has been already established as a tradition fostering students' creativity and heuristic thinking and creating a positive learning environment.

### 3.4 Virtual exhibition

Another educational concept stimulating students' creative participation was conceived in the form of a virtual exhibition [15]. The *"Hall of Fame"* blog [16] presents in cyberspace the best student works on the assignments of the disciplines Theory of Composition and Form Formation. This unique web-based presentation turned out to be extremely successful way to engage students, providing opportunity for personal expression in full compliance with the blogging culture of Gen Y. The competitive environment which originated challenged them to work hard so that their designs were approved for publication. Students who succeeded in finding a place in the "Hall of Fame" felt very proud and we observed that this raised their self-confidence and inspired them for further creative expression including participation in other design contests.


*Figure 1. Examples of posters announcing the events: Student conference, Student debate, Abstract readings, Video marathon*

## 4 CONCLUSION

To meet the challenges imposed by technological development modern education needs rethinking and restructuring. We realize that our students belong to a generation dependent on technology and it is our responsibility to integrate it as an educational tool in order to respond effectively to the changed learning needs and expectations. We are trying to consider the requirements of our students by including in the teaching a series of extracurricular activities supplementing lectures and seminar classes. Our main objective is to substitute traditional linear approach in education by offering alternatives which engage students more actively in the educational process and create learning environment based on interactivity and collaboration. The events we have organized in the last two academic years (conference, debates, abstract readings, workshop and virtual exhibition) were aiming to provide more flexible ways of studying, to encourage technology use and social networking for educational purposes, to provoke knowledge construction through research and personal experience, to inspire intrinsic motivation for learning, to promote student independence and peer cooperation.

Generally we can conclude with satisfaction that on average 60 % of the students participated in these extracurricular activities. For us, however, it is of great importance to receive feedback from our students whether they approve this educational strategy. Therefore, to investigate their opinion and to evaluate the effectiveness of the proposed activities we conducted a survey at the end of each semester. 52% of the students indicated that the main reason they participated in the initiatives was to show their creative potential, 40% - because the themes were very interesting, 34% - to receive a certificate, 29% - to be exempted from the exam, 5% - to prepare better for the exam /more than one answer was possible/. 88% replied positively to the question "Did extracurricular activities contribute to a better understanding of the material taught in lectures and seminars?" and 62% report these activities facilitated their preparation for the exam. Another survey question addressed the possibilities for creative participation and 85% confirmed that extracurricular activities gave enough opportunities for personal expression. Most satisfactory however is the finding that 98% of the students consider that acquired knowledge is relevant and will be very useful for their future career. These results prove that students learn more effectively when they feel engaged and see the real benefits of the obtained skills and knowledge. We also observed that the overall academic achievement level in the two disciplines has risen in comparison to previous years, which is another confirmation that the proposed teaching strategy is successful.

We tried to offer dynamic learning including discovery, analysis and interpretation which conform to the digital culture of Gen Y students and their expectations of more student-centred and interactive educational process. The teaching approach we implemented corresponds to generational characteristics such as confidence, team-orientation, achievement, customization, innovation and collaboration, and encourages every student to choose the most appropriate learning style. Since students are accustomed to social networking, as expected most of them (95%) approved the creation of the course facebook page and confirmed it has improved the communication with the lecturers and has facilitated learning. Another very useful product of our teaching strategy was the first CD of the series "Student Scientific-Educational Forums" which is already used as a helpful handbook.

Motivated by the positive outcomes, in future we plan to continue with analogous extracurricular activities, diversifying and improving them according to the preferences and requirements of our students. It would be a great challenge if the teaching methodology we propose is probated in other universities where design is taught to validate the effectiveness of this active learning paradigm for Gen Y students.

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# A NEW CONSUMERISM: THE INFLUENCE OF SOCIAL TECHNOLOGIES ON PRODUCT DESIGN

**Ian DE VERE**
Brunel University, London

**ABSTRACT**
Social media has enabled a new style of consumerism. Consumers are no longer passive recipients; instead they are assuming active and participatory roles in product design and production, facilitated by interaction and collaboration in virtual communities. This new participatory culture is blurring the boundaries between the specific roles of designer, consumer and producer, creating entrepreneurial opportunities for designers, and empowering consumers to influence product strategies.
Evolving designer-consumer interactions are enabling an enhanced model of co-production, through a value-adding social exchange that is driving changes in consumer behaviour and influencing both product strategies and design practice. The consumer is now a knowledgeable participant, or prosumer, who can contribute to user–centred research through crowd sourcing, collaborate and co-create through open-source or open-innovation platforms, assist creative endeavours by pledging venture capital through crowd funding and advocate the product in blogs and forums. Social media-enabled product implementation strategies working in conjunction with digital production technologies (e.g. additive manufacture), enable consumer-directed adaptive customisation, product personalisation, and self-production, with once passive consumers becoming product producers.
Not only is social media driving unprecedented consumer engagement and significant behavioural change, it is emerging as a major enabler of design entrepreneurship, creating new collaborative opportunities. Innovative processes in design practice are emerging, such as the provision of digital artefacts and customisable product frameworks, rather than standardised manufactured solutions.
This paper examines the influence of social media-enabled product strategies on the methodology of the next generation of product designers, and discusses the need for an educational response.

*Keywords: product design, participatory culture, design entrepreneurship, prosumer, producer*

## 1 INTRODUCTION

Social media (or Web 2.0) is emerging as a major enabler of design entrepreneurship and is facilitating new consumer engagement and design methodologies. New user groups are motivated to participate in the new product development process and the traditional roles of the consumer and the designers are being challenged and becoming more ambiguous. From a design perspective, social technologies present opportunities, challenges and risks as consumers assume new roles as co-designers, co-creators, co-developers [1] and with the utilization of 3D printing, co-producers. Additive manufacture and digital production technologies are encouraging the rise of the user-maker and enabling consumer-directed adaptive customization and product personalization. Concurrently, social technology interaction is providing new user engagement and collaborative opportunities; facilitating a new participatory culture, where consumers are active participants rather than passive recipients. This has implications for the practice of new product development as consumer expectations and behaviour evolves and co-creation becomes the norm. Industrial/product designers may increasingly find that their role is not to deliver a strictly defined and mass-manufactured product outcome. Rather, they may be facilitators in a global co-design process, or required to deliver flexible product platforms where (within designer-defined parameters) the user can adaptively customise, and personalize a product or service outcome. As product development and implementation strategies are increasingly directed through social media, it may be necessary for design educators to respond to a new model of product design where consumers are empowered and enabled in the NPD process and the designers' role is more facilitation rather than resolution [2].

## 2 THE NEW PARTICIPATORY CULTURE OF CONSUMERISM

Social technologies have led to the imminent promise of unprecedented user participation and collective content generation, sharing and personalisation. Product designers can now expect explicit consumer participation and active engagement in all stages of new product development, from user-centred research, co-design and marketing to product adaptive customisation. This 'participatory culture' noted by Jenkins [3], Benkler [4] and others, describes an actively engaged consumer model, where rather than being directed by the end product, the individual contributes directly to the product development or is engaged in its production.

Whilst most of the emerging participatory culture through social technologies has been observed in open-source software development, and other on-line media, the potential for community engagement throughout new product development is an emerging opportunity as consumer passivity lessens and new designer-user relationships and product meanings are expected. The increased consumer engagement with designers and the design process, whilst dramatically impacting product architecture and user ownership, also has the potential to transform possible consumers into product advocates.

### 2.1 Prosumers, producers and product producers

The proactive consumers or 'prosumers' identified by Tofler in his book The Third Wave [5] are those who are engaged in designing or improving products and services, participating in the outcome rather than being passive recipients. Toffler and later Ritzer et al [6] noted that prosumption was common in pre-industrial societies (the first wave), however the following (second) wave of mass manufacturing and marketisation separated society into the distinct roles of producers and consumers. Whilst the design and production of goods for personal consumption was commonplace prior to the industrial revolution, the dominance of the factory and standardised manufacture disempowered user-makers, and resulted in consumer passivity. Toffler's 'third wave' signals the reintegration of production and consumption, a concept that predates the impact of social media, but which is supported by Kotler's notions of a 'prosumer movement' [7]. Bruns [8] more recently noted the emergence of 'produsage' referring to user-led content creation and commons-based peer production typically in a digital media context, (e.g. Wikipedia) where the boundaries between passive consumption and active production are indistinct. These modern 'digital prosumers' [6], have paved the way for 'product producers' those consumers who actively contribute to product production which in a new product development context, is enabled by additive and digital manufacturing technologies [2].

### 2.2 Adaptive customization / product personalization

There has been increasing demand for mass customisation as consumers are empowered in the product development process. Historically it has been difficult to tailor products to the needs of specific users, due to the need for product standardisation resulting from the substantial upfront investment associated with manufacturing, particularly in tooling and assembly processes. However market demands and emerging technologies are facilitating a move to more unique and individual product solutions, with which a greater emotional attachment can be established.

Consumer-driven 'adaptive customisation' (where firms produce standardised products that are customisable in the hands of the end-user) [9] is significantly facilitated by digital production technologies that are not dependent on design-determining tooling. Additive manufacture greatly increases product produsage by enabling independent and personalised product generation in a minimal investment production environment. The potential for multiple product iterations, hierarchical scaling and product personalization, creates opportunities for unprecedented customer engagement enabling user-driven innovation. The potential of digital and additive manufacturing aligns with Anderson's theory of 'The Long Tail' [10], where endless choice creates endless demand and all market niches can be catered for and reached through the internet. Both 3D printing and social media are seen as disruptive technologies with great potential for peer-to-peer content sharing and co-creation and new consumer behaviour, such as produsage.

### 2.3 Co-creation

As technology has provided consumers with unlimited communication interaction both with other consumers and companies, consumers are increasingly empowered, and now desire a greater role in the process of value creation [11]. This co-creation process is now considered to be an important manifestation of consumer engagement behaviour [12]. This is particularly important in new product development where consumers contribute new ideas, or suggest product or service improvements, in a model of collaborative co-creation where the consumer is an active participant in the NPD process.

This participation has significant benefits with regard to product relevance and targeting, understanding motivations and addressing user needs, increasing product quality and market acceptance, and risk reduction. Consumer involvement in NPD process increases the probability of product success as consumers are more likely to value the product solution [11] and are more likely to move from a passive role to active and unsolicited product advocacy.

However, whilst consumers are able to clearly articulate needs and preferences, there can be inconsistencies in their interest, willingness and ability to participate constructively to the product development process, often lacking the prerequisite skills to contribute on more than a superficial level. Community generated ideas might be novel, but they may not always be feasible for production. Product success requires highly skilled co-creation collaborations between 'experts' and community, as is evident in creative collaborative communities and open source / open innovation models.

## 3 SOCIAL MEDIA AND THE DESIGN PROCESS

Social media which is "characterised by participation, openness, conversation, connectedness and sense of communality' [13], is enabled by Web 2.0 which results from innovation in functionality that allows simultaneous publishing, retrieval and modification by all users in a participatory and a collaborative fashion, also leading to user-generated content [14].

Whilst there is a large social dimension to Web 2.0 with content sharing sites (e.g. YouTube) and social networking (e.g. Facebook), blogs and microblogs (e.g. Twitter) and virtual world interaction, it is the potential of global connectivity to enable new product development that is the focus of this paper. Dittrich et al [15] examined software development and suggested that 'design' and 'use' should not be regarded as separate and sequential activities, questioning how these different, co-existing practices of design could be more deliberately placed in dynamic relation to each other. This suggests a deliberate strategy is required; one that simultaneously creates and demands engagement between design and use, in turn leading to a new form of consumer participation [16]. Resultantly social technologies require designers to think beyond the provision of artefacts and to deliver value to participants that may be independent of the final product outcome.

### 3.1 Impact throughout the design process

In recent years, companies have moved from a position of questioning the need for social media involvement, to requiring a cohesive and effective social media strategy. Whilst many companies simply connect with consumers as part of a marketing strategy, increasingly social media engagement is impacting through all business areas, in particular new product development. If one is to examine a typical product design process, such as in Figure 1, it is easy to understand the possible implications of a social media strategy on almost all areas of new product development.

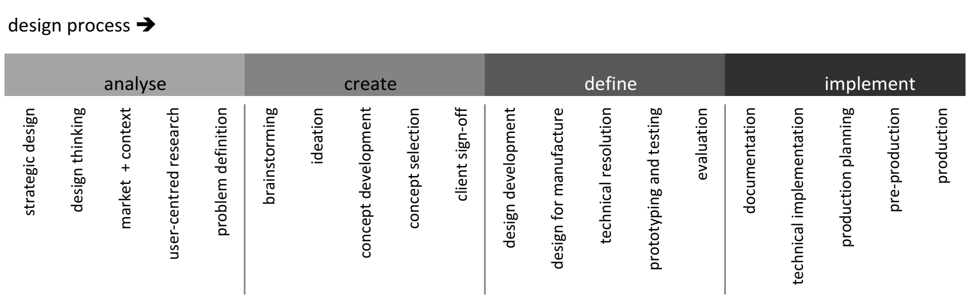


*Figure 1. A representative design process*

In the 'analyse' stage, designers can using crowd sourcing to engage consumers to develop product strategies, conduct market and user-centred research and problem definition, and conduct data mining and social diffusion research. In the 'create' stage, design activity from initial ideation through to concept selection can be supported by open-source collaborative design and consumer participation. The design development journey though the 'define' stage, may engage more skilled participants (i.e. qualified designers) through open-innovation platforms, whilst the 'implement' stage is enabled by digital production technologies that facilitate home production, customisation and personalisation. In addition, the project can be supported by a product implementation strategy that uses crowd funding to raise venture capital and generate pre-launch 'hype', draws on forums and blogs to develop markets, and sales, and social networking sites to analyse consumer behaviour and predict emerging trends.

### 3.2 Impact outside the design process

If we begin to see the designer not just as a supplier of standardized artefacts, but also as a facilitator of collaborative design experiences and the developer of flexible, customizable product frameworks, then social media must occupy a central role in this new design process. It is possible that future roles for designers may not be detail resolution, but the facilitation of product and service possibilities. Entrepreneurial co-creation may require designers to relinquish 'ownership' of the design outcome, instead providing the tools and expertise to guide consumers in product design, rather than delivering the artefact. Are design graduates adequately prepared for this new mode of product development?

### 3.3 The new design entrepreneur

A new model of design practice is emerging where designers will operate more autonomously from established financial, production and supply chains, but more closely with consumers who will be increasing engaged and inseparable from design and production activities. This new participatory culture will empower both designers and consumers, but in a model vastly different from the supply and demand role of the 20$^{th}$ century product designer. Social technologies can enable designers and consumers to be fully networked in an organizational and behavioural sense, generating consumer behavioural insights, improving communication and collaboration, and providing adaptive, customizable and personalisable product infrastructure. Whilst it is possible that increased integration of 'novices' into the design process may be detrimental to successful product outcomes, designers are uniquely positioned to be powerful enablers of value creation. But first they must understand the potential of social media as an enabler of design entrepreneurship and their own roles in consumerism.

## 4 THE SOCIAL TECNOLOGIES-ENABLED NPD PROCESS

Social media has enabled a new consumer participatory behaviour. Resultantly designers are responding with innovative new processes, where both expert and novice engagement are integrated into the product development process. This activity has seen the rise of new design entrepreneurialism and creative communities where peer-to-peer collaboration and open source design present new models of consumer interaction, and new business models are emerging.

### 4.1 Design research

Data mining and social diffusion research allow design researchers to understand changing consumer patterns and to make proactive, knowledge-driven product strategy decisions. Data mining searches data to analyse consumer behaviour, find hidden patterns and predict emerging trends, whilst social diffusion research [18] examines the way new ideas and technologies spread through social structures, revealing the evolution of trend spreading dynamics. Social media allows interaction with global communities, facilitating user-centred research. Designers are empowered to engage directly with target markets and end users to define the problem, test ideas and design solutions, and initiate participatory design activities. Broadly dispersed groups and targeted demographics are equally accessible and consumers are empowered by early engagement in the design process, with a sense of ownership over the final outcome. These early inclusive interactions move participants from passive to stakeholder roles, and even to advocacy of the design outcome. 'FrogMob' uses an experimental method of 'guerrilla' research, based on the idea that "anyone can channel their inner design researcher by looking for inspiration from everyday life." In this model, Frog Design conducts wide-ranging design research by encouraging a global audience to submit product-user experiences; this informs new product development. This crowd sourcing research helps designers understand human behaviour and more specifically how people interact with products, services and their immediate environment.

### 4.2 Crowd funding

Crowd funding websites have proven highly successful in assisting creative initiatives to be promoted, and financed through pledge-based fundraising. Sites such as Kickstarter, Indiegogo, Pozible, Sponsume and Quirky, enable designers to 'pitch' an unresolved product 'concept' without financial commitment or inherent risk. Designers can indulge in creative exploration and design risk taking with the knowledge that the project will only proceed with sufficient financial support from interested investors. The main benefits of this approach are that designs are tested for marketability, potential sales are measured and production is financed before too much development time is invested in the product; a distinct advantage for independent design entrepreneurs.

### 4.3 Open Making

With the phrase "everything is makeable, anytime, anywhere, by anyone" [17] in 2011 Studio Droog launched the 'design for download' platform where consumers could adaptively customise then download open-source furniture designs for private production. Using 3D printed and CNC routed components, these furniture designers were empowered to market and sell furniture to a broad market without requiring production and distribution facilities. This model has now been replicated in several forms including SketchChair (a Kickstarter-funded project providing open-source furniture design software which consumers use to design their own CNC routed chairs) and Open Desk, a global community of designers and makers offering products that have been designed for digital fabrication. This 'Open Making' model, which was featured in the Design Museum's "The Future is Here" exhibition, connects customers, designers and makers empowering all stakeholders.

### 4.4 Crowd storming

Open innovation platforms are global collaboration communities that share ideas and opinions to solve problems and develop product or service solutions. Many crowd sourcing sites (e.g Quirky, Jovoto, Innocentive, Ahhha), uses social ideation or 'crowdstorming' to drive product innovation. Crowdstorming leverages the efficiency of social media coupled with innovative workflows to access external talent anywhere at low cost, brainstorming at a global scale for ideas and insights and critical review. The power of brainstorming with thousands of people, rather than with a small internal team, is the essence of crowdstorming. Crowdstorming is evolving from simple open innovation idea searches, to complex interactions where 'crowds' are engaged in specialised tasks. This enables companies to develop new consumer engagements and to open up their innovation processes. Many companies are now integrating crowdstorming into their business models to bring better products and services to market, for example GE's Ecomagination challenge to innovate power grid technology, Lego's Cuusoo platform (where if an ideas gets 10,000 votes Lego will consider making it), and the Starbucks involvement in the Betacup challenge to eliminate paper cup consumption. Another model of crowdstorming involves open-innovation platforms which focus on social activism through design (e.g. OpenIDEO, Design21, DESIS Network). These collaborative platforms challenge designers to develop solutions to societal and environmental problems for the collective social good.

## 5 CONCERNS AND IMPLICATIONS

Traditionally new products emerge from a quality controlled process where design and engineering 'experts' collaborate to resolve a product for usability, safety, adherence to standards, and for manufacture. Many in the design community are concerned by the potential for speculative open design work to be superficial and poorly considered and for consumer-adapted design to be unresolved and lacking appropriate professional rigor. This could result in poor quality or unsafe products, combined with a lack of accountability and unclear liability responsibility. Who is responsible for a product failure causing injury or death, when the product is downloaded, modified and produced by the consumer from an open-source design platform?

We also need to understand the potentially disruptive impact of open collaborative design and co-creation on the established design industry. Whilst these new methods of engagement are highly motivating for design entrepreneurship especially in the hands of a new design generation, does collaborative design devalue the contribution of professional designers? What will be the economic impact on the creative industries of peer-to-peer product development outside traditional business models? Is this a paradigm shift that will require a compete reformation of the design industry?

How do we handle intellectual property? Competitive advantage has always been protected by patents and design registrations, but open design platforms provide opportunities for endless adaptation and plagiarism of designs in a spirit of collaboration that is highly disruptive to existing business practices.

There are huge opportunities for a renaissance or regeneration of industrial design, but new product development processes must adapt to different and constantly evolving consumer interaction.

## 6 EDUCATIONAL IMPLICATIONS

How do we prepare design students for these new work practices? Although traditional design skills and expertise are still relevant, are they enough? As leaders in any product development process, designers will always need specific 'design' expertise especially as their collaborators may well be novices. However graduates will need to also be entrepreneurial, independent and collaborative and have a greater understanding of consumer behaviour and the potential of social interaction. Social technologies whilst disruptive for established business models, are potentially liberating for designers and may herald a new design entrepreneurship, driving product innovation towards more consumer focused and relevant product outcomes, with significant consumer/community engagement. The issue is whether existing design curricula adequately prepares students for entrepreneurship design practice, and the consumer engaged, co-creation models, which will characterise 21$^{st}$ Century design practice.

As educators, we have an obligation to ensure that design graduates are capable of delivering an effective product implementation strategy that exploits the potential of social technologies, rather than merely responding to a brief. Students must be taught to facilitate flexible, consumer-designer-product interactions where consumers are engaged and empowered throughout the new product development process. Accordingly, design curricula must respond to emerging social media opportunities and product implementation strategies, ensuring new modes of consumerism and product languages are enabled without compromising quality, usability, user safety or satisfaction. These are new challenges.

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# RP VS WORKSHOP: HOW MODELLING METHODS AFFECT EARLY DESIGN DEVELOPMENT

**Gary UNDERWOOD**
Bournemouth University

**ABSTRACT**
The use of physical modelling has long been established as a crucial part of the Product Design process. In recent years Rapid Prototyping (RP) has played an increasingly important role in this area, within industry and education. But exactly how RP fits within a modern Product Design curriculum, and the extent to which it is utilised, are contentious issues. While some Universities are happy to make use of RP throughout the design process, to date Bournemouth University (BU) has favoured traditional model making skills during the concept testing stage. However, while traditional methods may present a number of advantages over RP – such as more direct scalar and tactile feedback, and a broader understanding of materials – they may also have a detrimental effect on students' designs. The limitations of producing an accurate model by hand may well be responsible for restricting design development, while the use of new technology may instead encourage a wider range of possibilities.
This paper seeks to explore the influence of RP and traditional workshop skills during the concept modelling phase of Product Design. Through the use of a comparative study involving design iterations with different modelling methods, the early design process is examined with particular focus on the experiences of the students themselves. The results highlight the benefits and drawbacks of using RP during concept testing and how new technology can influence student behaviour at this crucial stage of design development.

*Keywords: Rapid prototyping, product design, foam modelling*

## 1 INTRODUCTION

Despite the technological advances of the past fifty years physical models still fulfil an important role within Product Design. Whilst CAD software has developed to provide increasingly realistic renderings and analysis of virtual models, the physical model delivers a whole range of immediate scalar and tactile feedback, as well as offering a valuable tool for demonstration, evaluation and marketing purposes.
At Bournemouth University (BU) model making forms an important part of the BA/BSc Product Design course. During the three years while they are present at the University, students are timetabled for around 530 hours within the prototyping workshops. As well as producing a number of fully working prototypes, students are encouraged to use models throughout the design process to evaluate and refine their designs. These models and prototypes have tended to be almost entirely produced using traditional model making and engineering skills, despite the University owning a number of RP machines, including a Stratasys Titan Fused Deposition Modelling (FDM) unit capable of producing high quality ABS items. The course's emphasis on encouraging traditional skills has meant that this equipment was only utilised for final prototype parts that were impossible or too time-consuming to make via other means. Consequently less than half of the students would gain experience in RP, and then only as a prototyping shortcut rather than as an integrated part of the design process.
This heavily restricted use of the facility represents not only an ineffective use of resources but also a wasted opportunity for educating students in the variety of uses of a tool that is increasingly considered revolutionary for the future of design and manufacture. The rapid worldwide expansion of additive technologies in recent years, not only within education and industry but now in the home, is clear and 3D printing continues to demonstrate its usefulness in all phases of the design process. An investigation was therefore carried out into the potential ramifications of extending RP into other areas of the Product Design (PD) course.

## 2 LITERATURE REVIEW

Much has been written about the practical consequences of having a rapid prototyping facility. The savings in workshop manpower, equipment and space have been weighed against the expense of investment in RP equipment. Material costs have been compared and build times have been analysed. The considerable health and safety advantages of additive technology have been championed.

However, worthy though these considerations are the concerns at BU related more to the educational experience of the Product Design students themselves and whether RP could be used to aid their development as Designers. A considerable amount of literature has featured RP in design courses around the world over the past twenty years, but a large proportion of it focussed on the potential of the new technology rather than presenting evidence of the results of its use [1][2][3]. This literature, in common with most of the popular media coverage surrounding RP, tends to be notably positive and optimistic about the introduction of additive technology, though it is usually accompanied by little or no supporting evidence.

Although evidence-based research studies might be expected to offer a more balanced view, the literature from courses which have replaced traditional model making with RP tends to be similarly skewed in favour of the benefits of rapid prototyping. However Helbling and Traub's 2008 study [4] highlights many valid issues, perhaps most importantly the complexity of form that additive technology can reproduce, therefore ensuring that designs are "no longer hindered by manufacturing difficulty". This view was echoed in a slightly different way by Flowers and Moniz [5]: "Some prototypes may be ingenious solutions to a problem, but building them could go beyond the capabilities of students and their equipment." This raises the complex and important issue of the relationship between the student's intended design, the model and the method of manufacture.

In 2010 Forkes [6] noted the discrepancy that often occurs between design drawing and model due to a shortage of skills on behalf of the student. This appears obvious: RP models will always be more faithful representations of the original CAD drawing (though not necessarily the designer's vision) than hand-made models. However it is also possible that the standard of design work produced via CAD/RP is genuinely higher, irrespective of the quality of the model. In 2006 Wilgeroth and Gill [7] claimed that the adoption of RP, in the form of CNC, at University of Wales Institute Cardiff had eliminated the phenomenon of "design for model making" - where students purposely produce designs that they are likely to find easier to prototype - although supporting evidence was lacking.

### 2.1 Comparative studies

Comparative studies looking at whether RP and traditional model making lead to different student experiences are more scarce. However Greenhalgh's 2009 study [8] of Utah State University Interior Design students, while drawing few conclusions, raises many interesting questions. Assessing the differences between two small groups simultaneously designing a chair with RP and traditional methods, a number of interesting suggestions are made:

- That RP can level the playing field for designers of differing model making ability.
- That RP can more easily enable quick revisions to be made to designs.
- That traditional model making restricts and simplifies a designer's initial ideas, while RP has the opposite effect of extending and "magnifying" the original concept.

These ideas echo the claims of other researchers [5] [6] [7], but particularly intriguing is the possibility that, by encouraging students to "test the capabilities", RP pushes students to explore options that may have been discounted – or not even considered – at the beginning of the design process.

The early stages of product design are vitally important, and models can perform a crucial role in early design development. It is possible that RP may be able to play a part in these earlier stages of product design development and may bring considerable creative benefits.

A comparative study was therefore devised, focussing exclusively on PD students, to explore the influences of both RP and traditional workshop skills during the concept modelling phase. Five key areas were selected for particular attention:

- Whether 'design for model making' exists for RP.
- How modelling methods affect design development.
- At what stage RP should be introduced into the design process.
- Whether students find traditional model making or RP limiting or liberating.
- Which method the students feel contributes most to a successful design.

## 3 STUDY METHODOLOGY

Second year PD students at BU currently undertake a 20-credit Design Visualisation unit, consisting of two consecutive 10-week elements, each running for two hours per week. The first element covers 3D CAD modelling and rendering; the second – taught by the author – covers physical concept modelling in the workshop. This second half of the unit offered an ideal opportunity to conduct a comparative study with minimal disruption while still maintaining relevant educational content for the students. As well as introducing students to RP at an earlier stage in their studies, it would also offer a useful link to the 3D CAD modelling element undertaken in the first half of the unit.

For ethical reasons, and to allow comparisons to be made by the students themselves, it was important that the entire group experienced both RP and traditional model making. This presented a problem in deciding which method should be used first. Running the RP exercise prior to the workshop exercise could well elicit different responses to running the RP exercise after the workshop exercise. However this also presented an opportunity to explore the relationship further: by dividing the group in two and running the exercises in different orders for each group, both sets of students would be able to contribute, offering different but complementary viewpoints.

The students were therefore instructed, on completing the first, CAD-based half of the unit, to prepare concept sketches for a laptop computer mouse. During the first week of the second half of the unit one group was asked to create their design using SolidWorks CAD software while the other group used Styrofoam and urethane foam. In week three - allowing a period to RP the CAD models - the two groups were asked to swap methods, developing and refining their designs if necessary.

### 3.1 Epistemology

The majority of the studies conducted into the use of RP in design education have been based on a positivist approach. In some cases this approach has been justified: in determining the allocation of time or resources it is possible to apply quantitative techniques and obtain valid and specific results. However, when exploring elements such as frustration, enjoyment and influences, this approach produces “research with human respondents that ignores their humanness”, in the words of Lincoln and Guba [9]. Therefore a predominantly interpretative epistemology was employed, in order to generate the rich data required to investigate complex matters such as creativity and motivation, and to allow greater scope to pursue the relevant issues in a more flexible way as they arose during the research.

Focus group discussions took place to gather the bulk of the rich data required, and prior to these a questionnaire was issued to all the volunteers in the study. Although over-detailed quantitative analysis of the responses would be inappropriate, the questionnaire was extremely useful in identifying general trends and opinions. Furthermore, the provision of a large number of free text options within the questionnaire helped to raise issues previously not considered, as well as providing further comment and improving the validity of the data.

## 4 RESULTS

A total of 42 students agreed to participate in the study, all of whom completed the assignment by producing initial concept sketches, a printable CAD model and at least one foam model. 30 students returned completed questionnaires, and 13 of these students also engaged in the focus group discussions.

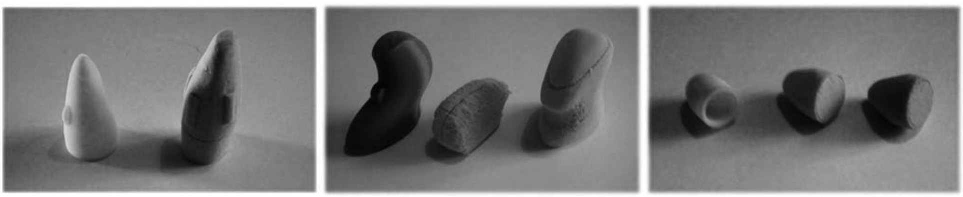
The questionnaire and focus group questions were specifically designed to focus on the five core issues previously identified, and the results were as follows.

### 4.1 Design for model making

What is particularly evident is the acknowledgement by the students that advance knowledge or consideration of the modelling method did indeed influence their concept drawings. 72% of the students admitted that the knowledge that they would have to create a physical model influenced their initial design. For traditional modelling the most commonly cited reasons were because of limitations imposed by available materials, processes and time-scales, rather than because of a lack of modelling skills. Moreover, students confirmed in discussions that this behaviour is not confined solely to this project: “Whenever we’ve been designing…we kind of develop our designs into something that we know that we can make.”

Crucially, the group who produced their RP models first (from here on referred to as group A) were slightly more likely to admit to 'design for model making' than those who produced their foam model first (group B). Unlike the traditional models, which were typically "kept simple" irrespective of modelling ability, the RP models were influenced in different ways according to the student's ability with CAD. Those with lower skill levels professed to keeping their designs simple, while some of the more advanced practitioners purposely created more complex designs to take advantage of the abilities of additive technology. In addition, the software tool options played a part, by encouraging students to design extruded shapes and regular curves, for example.

Further striking evidence of the effects of advance knowledge was provided by the models themselves. Group A were much more likely to produce 'radical' design concepts, with almost three times as many models with non-traditional mouse shapes than group B (Figures 1, 2 & 3).



*Figures 1, 2 & 3. Examples of non-traditional mouse shapes produced by group A*

### 4.2 How modelling methods affect design development

Both groups reported a high number of alterations to their designs in first transforming their concept drawings into a three-dimensional object. Significantly, the majority of these changes appeared to be relatively cosmetic for group A, working with CAD while group B, working with foam, documented changes that were primarily concerned with ergonomic issues.

In part this explains the divergence in results concerning intentional design changes when modelling methods were swapped. While just over half of group B made changes in converting their models from foam to RP (Figure 4), over 80% of group A were still making intentional design changes in converting from RP to foam (Figure 5). The majority of the changes noted by group A were issues of ergonomics and scale - "Moved buttons and finger positions"; "Made the height smaller" – reflecting the obvious problems in gauging such issues accurately in a virtual environment. By contrast, group B seem to have resolved the majority of the design issues in foam before moving on to CAD.

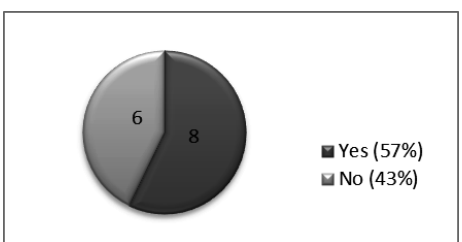



*Figure 4. Design changes for 2nd model (group B)*

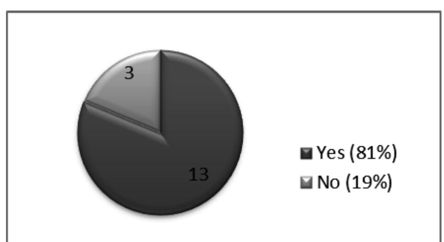



*Figure 5. Design changes for 2nd model (group A)*

The rapid turnaround and instant physical feedback of working with foam inevitably played a part too by speeding up design iterations. Although roughly the same amount of time was spent producing the CAD model and foam model, over 70% of students were able to produce two or more models, with some producing four or more.

As well as intentional design changes, group A reported a high incidence (44%) of unintentional design changes. It was evident that many of the designs first produced via RP had developed in such a way that made them difficult to reproduce in foam "because on SolidWorks I can do what I want, while on blue foam you're limited with the tools".

The phenomenon of 'accidental design' was also observed on several occasions with students working in foam: "The first design I had, the off-cuts from it were better than the original one. So I ended up just playing with them and they worked out better." The students agreed that this was something unlikely to occur with RP.

### 4.3 At what stage is RP most effective?

One of the clearest results from both the questionnaire and the focus group discussions is the general consensus amongst the students that rapid prototyping is particularly useful towards the end of the concept modelling phase. The main reason given for this is the ability to reproduce faithful variations of the design once most of the major design work has been accomplished, but it was also noted that – in this instance – RP represented the intended material of manufacture more successfully. It was also generally agreed that the RP model looked “more professional”.

With regard to the earlier use of RP the vast majority of both group A and B agreed that foam modelling was better to start with than CAD, as it enabled quick resolution of ergonomics and scale, and was generally better suited to the ‘fuzzy front end’ of a project.

However it is worth noting that some students argued forcefully that early use of CAD had been extremely valuable in helping to develop their designs, and it is plain to see that these designs would have developed very differently – and arguably less successfully – if foam had been used first.

### 4.4 Limiting or liberating?

The students’ attitude towards foam modelling was clearly dependant on whether they had modelled their design in CAD first. While 64% of group B found foam modelling fairly or very liberating, the corresponding figure for group A was only 32% (Figure 6). These results appear to tie in with the theory that at least some of the designs modelled in CAD had developed in a way which made them difficult to model by hand.

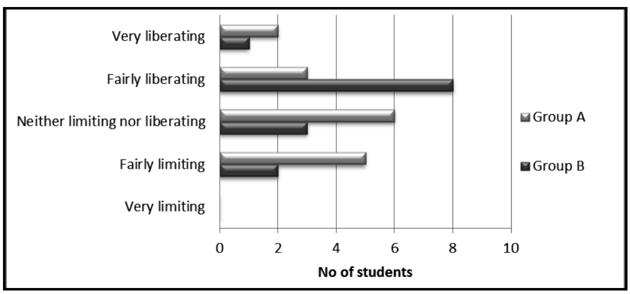



*Figure 6. Foam modelling: limiting or liberating?*

Comments about foam modelling, while mainly positive, reveal the often ambivalent attitude towards the process: “More satisfying [than RP] but frustrating at the same time. I feel more proud of the foam model”. One of the particular frustrations voiced about working with foam was the difficulty in going back on errors or experiments in shape: “You can experiment more with CAD, and go back and forwards to get what you want. But with hand [modelling], once you’ve gone too far that’s it”.

RP was less divisive in terms of whether it was found limiting. Only five of the thirty students questioned found it ‘fairly limiting’, and none found the process ‘very limiting’. There was a clear difference of opinion, however, on whether RP stifles or spurs creativity, and again this was linked to skill level. One student less confident with CAD claimed, “You can’t really design something creative on SolidWorks”; another, who described himself as a CAD expert, claimed that it “opens up a lot of doors when it comes to creativity”.

The creative limitations of the software itself were also noted. Some students referred to the level of freeform subtlety that can be applied in hand modelling, and the frustration with the difficulty in applying similar subtle changes to virtual models.

### 4.4 Foam or RP – or both?

It would not be unreasonable to expect that a design would ‘improve’ as it developed, and in the case of group B this is reflected in the fact that a clear majority, 64%, expressed a preference for their final model, the RP version. However in the case of group A only 40% chose their final, foam, model, with slightly more preferring their earlier RP version.

This would seem to provide further support for the view that some of the CAD models of group A had developed in a way that was subsequently difficult to model in foam. Despite this, it is important to stress that not one of the students expressed an opinion that the foam modelling had been unhelpful or

a waste of time, even amongst those who felt the RP version presented the most successful design.
The usefulness of both methods – and support for the use of an iterative process in concept modelling - is expressed by the fact that every single student rated their first model – whether foam or RP – as ‘fairly useful’ or ‘very useful’, with over three-quarters selecting the latter.
There was overwhelming evidence that both types of modelling were felt to be important for successful concept design development. None of the students expressed a view that CAD or foam alone would have produced equally successful results, and most were vocal in their support for mixed modelling: “Both the RP and foam model helped when designing. They each play a part and have their own positive and negative aspects but should be used together”.

## 5 CONCLUSIONS

The evidence obtained clearly points to the widespread existence of “design for model making”, not just during this project, but across most – if not all – of the projects on the PD course where students knew they would be expected to produce a model of some kind. In the majority of cases this resulted in producing a simple concept that could be easily manufactured within the timescale. Most importantly, the knowledge that the model would be produced via RP did not prevent design for model making occurring, though – in contrast to traditional modelling – the students who were more skilled at CAD tended to use the opportunity to complicate rather than simplify their concepts. These findings run contrary to the claims of previous researchers [9].
The perceived wisdom, including that of the students themselves, is that it is most beneficial to undertake foam modelling prior to RP. However, many of the students on this project achieved great success – and tended to produce more ambitious designs – by using RP first before moving on to foam. What is certain is that the order of modelling methods makes a difference to the final design: it seems unlikely that the designs would have developed in the same way had the order of processes been reversed.
By introducing students to RP at an earlier stage in product development, they gained a lot of important knowledge about how this technology can be used effectively, as well as the potential drawbacks. Even those students who produced more ‘RP-friendly’ designs conceded that working in foam was a vital part of the design process. Both RP and traditional model making clearly have something to offer, and on this project both processes were judged equally necessary to maximise the potential of the design.
Most importantly for Bournemouth University, the experiment was viewed as a great success by staff and students alike, and a valuable addition to the PD course.

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# INTEGRATIVE PRODUCT CREATION – RESULTS FROM A NEW COURSE IN A LEARNING FACTORY

**Sinan UGURLU and Detlef GERHARD**

TU Wien, Institute for Engineering Design, Mechanical Engineering Informatics and Virtual Product Development Research Group

**ABSTRACT**

This paper describes a new higher education course "Integrative Product Creation" in the bachelor curriculum of mechanical and industrial engineering and its implementation in the TU Wien Learning and Innovation Factory (LIF). LIF is a faculty-wide cooperation of three institutes combining engineering design, production technology, and industrial engineering aspects. This new didactic approach has an integrated teaching concept with a real product "slotcar" and real processes. The aim of this program is to practice the complete generation of a slotcar from product conception to serial production. The paper presents also the practice oriented learning in the design education regarding the design for X approaches especially applying DFMA (Design for Manufacturability and Assembly). The paper reviews experiences and analyses students work during their practical training to understand the transference of engineering-based knowledge into design practice.

*Keywords: Learning factory, integrative product design, design practice, design education.*

## 1 INTRODUCTION

In the last two decades, fresh graduates may not effectively accomplish the product development processes in a life cycle context after an engineering program, even though companies prefer to employ engineering graduates who can implement engineers' tasks without on-the-job training [1]. Moreover, many students don't have enough stimulation and implementation opportunity to perceive their intelligence and creativity in the rigid confines of the lecture hall, which caused students to dropout engineering education without seeing the relevance of their required courses to the actual practice of engineering [2]. These are the key problems of traditional education. The main option for this problem is to bridge the gap between what is taught in classroom and what students need in real-life. Therefore, the teaching and learning settings must be modelled as closely as possible to the actual working context and process with a high degree of realism and clarity [3] [4].

In recent years, many novel practice-based contexts called "learning factory" or "teaching factory" have evolved to provide a new interdisciplinary and real-world problem solving environment in engineering education. Learning factories offer a new approach to understand the interdependency of design and manufacturing in real-world and also provide a balancing between engineering science and practice. The main aim of this approach is removing the traditional boundaries between academia and industrial practice by the combination of lectures with application and hands-on experiences [6] [2]. Learning factories are a solid opportunity in design education for teaching students how to do the design. The design courses at universities could be improved with learning factories depending on the key point ''to learn how to design'' and on the other hand, industrial focus in design of products and systems [1].

To practice design knowledge, design methodology in engineering education and problem solving techniques and also improve the non-technical skills, for example, communication skill and teamwork for this students have to come in touch with a real industrial case. To achieve these goals, a learning factory was realized in order to test and implement alternative education and training methods. This paper is organized as follows. Section 2 describes opportunities to develop competences and skills in the learning factories and design education. In Section 3 the didactical approach and concept of the LIF is presented. Section 4 reflects the results of the case study and summarizes first findings of the participant's experiences. Section 5 concludes the paper and highlights further improvements and future perspectives of LIF.

## 2 METHODOLOGICAL APPROACHES FOR COMBINING THEORY AND PRACTICE TO IMPROVE COMPETENCES AND SKILLS IN A LEARNING FACTORY

There are a number of learning factories that have been already established worldwide and these are varying in different learning contexts, for example, lean manufacturing, process optimization and energy efficiency [6]. Besides LIF, the learning factories in the German-speaking countries include the Process Learning Factory CiP at the Institute of Production Management, Technology and Machine Tools (TU Darmstadt) focused on manufacturing and lean production [4], the Department of Factory Planning and Management (Chemnitz University of Technology) directed on the Experimental and Digital Factory (EDF) and also the Institute for Machine Tool and Industrial Management of the Technical University of Munich included two different learning factories for Energy Productivity and Lean Production [7]. In contrast to the mentioned learning factories, LIF focuses on practice complete generation of a product from product conception to serial production.

Learning factories have physical and digital environments. The physical environment includes real system components like machining, assembly, logistics. Modelling, visualization tools are parts the digital environment [7]. Therefore the integrative product development in a learning factory has to offer the possibilities to transfer digital models to real products for testing and evaluation. Both physical and the digital environments should be well integrated to create an interdisciplinary and practice-oriented education in learning factories.

As mentioned above, the learning factory with its physical and digital environment provides a teaching and learning concept, capable of transforming theoretical knowledge into practice more effectively. This is a significant challenge for graduates who want to be able to solve complex and realistic problems in their working life. However, students learn at universities often inactive knowledge and this is why students are not able to improve their skills and competences in a realistic setting. The key purposes of a learning factory are improvement of design skills and problem solving competence.

In order to develop competences it needs practice oriented learning environment because that brings the learners into the focus of the activities. Major building blocks of a learning process are shown in figure 1 for a good understanding for the development of competences.

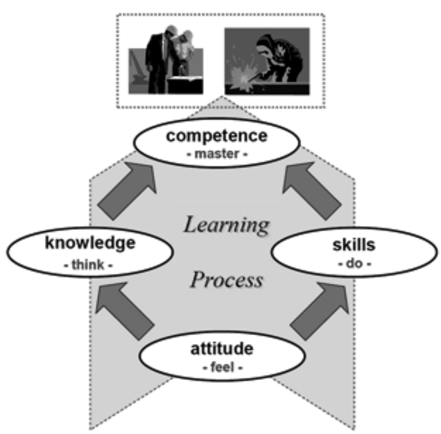


*Figure 1.The buildings blocks of the learning process [8]*

At this point skill is defined as ability to apply knowledge and use the know-how for the fulfilment of well-defined tasks. It may be cognitive (e.g. creative thinking) or practical (e.g. the use of methods and tools). In the context of a learning process, skills are, for example, observation and replication of actions, task reproduction from instruction or memory and also automated management of activities.

Competence is capacity to handle certain situations or complete a job. It depends on many factors, for example, different types of knowledge, attitudes, self-confidence and social skills [8].

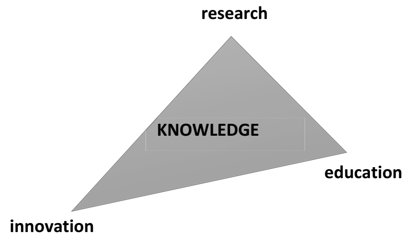


*Figure 2. The knowledge triangle in manufacturing [8]*

Knowledge, skills and competences are core terms in a learning factory to develop a problem solving capacity. The learning factories provide firstly a bridge between academia and industry and they create an area for the transferring of knowledge from research into innovation or real-life and also develop skills and competences from education into innovation. Therefore, research, education, and innovation (see Figure 2) are fundamental and strongly interdependent drivers of the knowledge-based society [8] and these drivers have to be integrated into a single initiative in order to promote the purposes and future perspectives of the learning factories.

## 3 LEARNING AND INNOVATION FACTORY: A CASE STUDY FOR INTEGRATIVE PRODUCTION EDUCATION

This part of the paper describes the practice-based and innovative concept of and student's tasks of the course "Integrative Product Creation". Further, it summarizes the aim of the combining learning factory and design for manufacturing and assembly (DFMA) aspects.

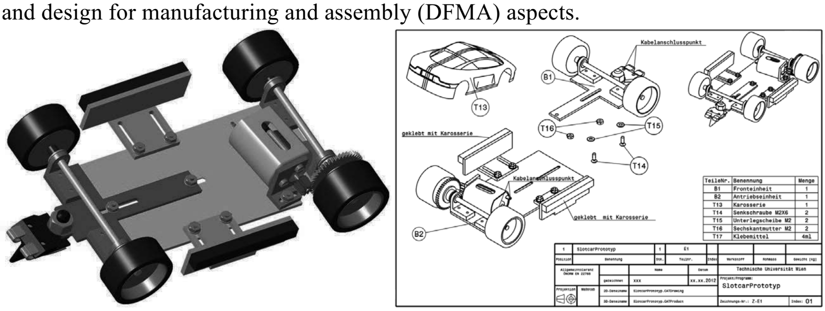


*Figure 3. 3D model and assembly group of slotcar prototype*

The slotcar prototype was designed and produced (see Figure 3) on the scale of 1:24. It has different components (purchased and production parts) and assembly groups. Therefore, students are able to be flexible to improve the prototype. The context of course consists of planning and design, engineering, manufacturing, assembly and also quality assurance. Figure 4 shows the layout of the LIF and its components regarding the material flow.

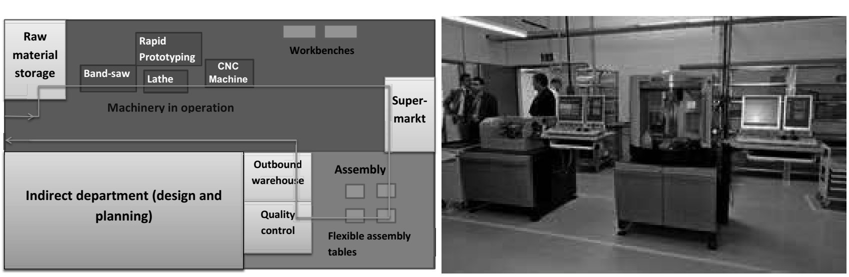


*Figure 4. Layout of the Vienna University of Technology Learning and Innovation Factory*

The aim of the course is the optimization and development of the prototype for the production of 100 slotcars according to manufacturing cost, lead time of the manufacturing and assembly process, and quality.
In the section of engineering design participants begin with product development, especially design. Each team begins with analysis of the already produced slotcar prototype. Participants firstly focus on structuring of the product and evaluation of design alternatives regarding the design for X approaches. Then they design an assembly fixture and manufacture it with 3D printer, finally they prepare 3D models, drawings, operation and assembly plans for further processes.

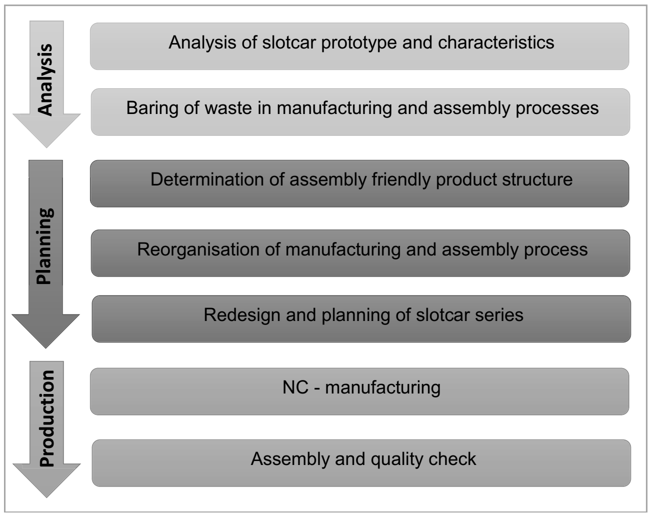


*Figure 5. Steps of the Integrative product development*

The next section focuses on manufacturing technology and production systems. This includes materials management, operation planning, NC (Numerical control) programming, and manufacturing of the improved parts of the product. And the final section consists of industrial engineering and assembly. Students plan assembly process and operations according to time and quality.
At the beginning, the course includes also a traditional lecture for theoretical preparation of participants to the tasks of learning factory (see Figure. 5). In the lecture, ‘‘Design for X’’ (DfX) methodologies, the DFMA (Design for Manufacturability and Assembly) is considered and emphasized, since both are highly apparent cost reduction drivers in the early stages of product design.

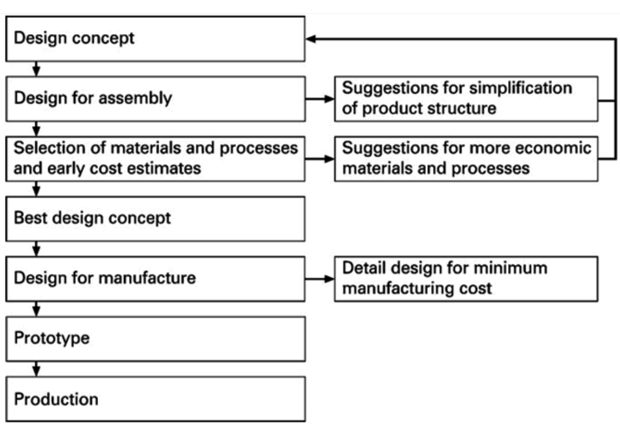


*Figure 6. DFMA process [1]*

The optimization of manufacturability of the slotcar and the minimization of the effort of slotcar assembly must be considered by the participants according to the DFMA process (see figure 6) in the learning factory. In summary, within the learning factory a team of students develops, plans, and manufactures a real product from prototype to series in for optimizing cost, quality and time. Therefore, the course promotes a holistic consideration of product creation process so that students are able to identify the impact of their design based decisions for the manufacturing and assembly process. Moreover, it combines theoretical learning experiences with practical application and improves knowledge, skills and competences of participants, especially in design engineering.

## 4 RESULTS OF THE CASE STUDY

In this section, the results and students' feedback in the first two years (2012 and 2013) of our program are described and discussed. Totally seven teams with four students participated in the first two years and after 2 weeks praxis in the LIF according to the described phases in section 3 all students or each team accomplish to develop and produce their own improved slotcars. In figure 7, two different designs of slotcar are shown and these are just two from many optimized slotcars in the LIF.

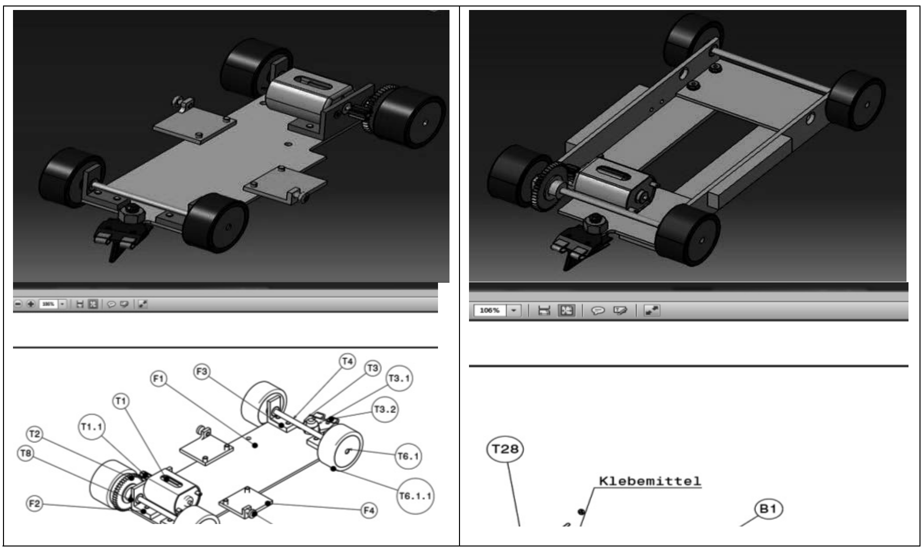


*Figure 7. Two new developed and produced slotcars*

According to the final presentations of students and their feedback, also observation of facilitator on two weeks practice, the course was very successful. The educational objectives of the course, i.e. the desired skills which we want our students to develop, for example, students were very creative and communicative. Each team improve new slotcar with implementation and optimization of DFMA.

During the course in the LIF students used the methods they had learned in the lectures and all decisions were discussed within the team. Their developments and idea were also discussed with facilitators within a final open presentation. Students reported their experience in the practice-oriented LIF and mostly, they made positive appreciation. Here are some comments from Students: "Applying theoretical knowledge and methods to solve real problems with social interaction in a technical working system was for me the first step in the engineering", "LIF provides a good opportunity to make errors and failures with our knowledge and see the results and learn from them", "It helps to understand methods which we hear and learn in the classroom". After considering students feedback some objectives were improved in 2013 compared to 2012, for example, effective integration of the project management methods.

In the LIF, students analysed the product and its development process from different points of views, and then after discussing their ideas within the team they implemented actively operational objectives of the course and realized their decisions from design concept to production of the slotcar. Each teams achieved a decrease of manufacturing costs between 20 – 25% by applying the DFMA aspects. An important point for the success of the course is final testing and a tournament with the slotcar because the competition aspect generates a creative environment and keeps students highly collaborative and motivated with the challenging racing option with their self-designed slotcars.

## 5 CONCLUSIONS

In this paper, a new approach for the practice oriented learning is presented with the purpose to highlight the problems from student and academic perspectives within the LIF and also the areas of opportunity for improvement of teaching and learning for the product design program. Most importantly, this approach is a new step for understanding the limits of the realization of engineering-based knowledge into design practice and manufacturing.

The introduced approach for integrative production education is a successful and practice-based engineering curriculum and provides an effective learning environment. The results show that students of practice oriented learning factory have significant advantages over traditional engineering education, because it addresses to balance theoretical knowledge in product design and realization. Moreover, it enables students to develop their professional skills.

Learning factory provides implementation of alternative education and training methods so that it will continue to evolve and expand, it becomes a core part of an engineering education. It is a challenging option to bridge the large gap between learning and work in real-life with its key characteristics such as interdisciplinarity, immersive learning environment, problem-based and action-oriented learning in comparison to traditional classroom formats.

In order to enable a continuous improvement of the course it requires identifying and generating competency-oriented and didactical new strategies that may be employed in the learning factory. At this point, application of design methodologies in integrative production education is very significant because the participants can apply design knowledge more effectively and accomplish creative-design more systematically and rationally.

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# PUTTING SOMETHING INTO PLAY - REFLECTIONS ON VIDEO AS A CREATIVE TOOL IN DESIGN

**Vibeke SJØVOLL**
Oslo and Akershus University College of Applied Sciences

**ABSTRACT**
In design, video is typically used as a tool for presentation, instruction, or observation. The use of video for creation and discovery as part of the design process is new terrain. This article explores how video as a tool for creation facilitates artistic expression and critical thinking in design education, and consequently how it "puts something into play".
This study reports the experiences from a product design course that involved the exploration of the potential of the video medium. One of the videos produced during this course is analyzed through an initial description and further explored by semi-structured interviews with the participating students. One unpredicted outcome of the analysis was that the projects incorporated the element of play on multiple levels. Furthermore, it suggests that the use of video as a sketching tool to explore a design task encourages an experimental approach, and testing of ideas in real-life situations with real people.
The study mainly reflects on how video as a tool of creation can put things into play in design education. This is explored in light of aesthetic theory, with particular reference to Hans Georg Gadamer's idea of art as play in his book *Truth and Method* [1]. The findings suggest that the unexpected effects of putting something into play support discovery of things not already known.

*Keywords: play, video, aesthetic practice, design, art, education*

## 1 INTRODUCTION

### 1.1 Video as a creative tool

In terms of both conceptual and visual experience, video as a medium offers multiple channels for discovering and expressing aesthetic ideas. The most in-depth exploration of the inherent qualities of video is commonly found in fine art. In product design, video has mostly been seen as a tool for the presentation of concepts or finished projects, as an instructional tool, or in user observation and research. Video has rarely been used as a tool for creation and discovery in the design process itself. This article reports the experiences of first year master students in product design on a course where this potential of the video medium was introduced. These students had no prior experience of using video as a tool or means of expression before this course.
As representatives of the first generation that has grown up with digital media and technology, it seems appropriate that they should develop these skills through the use of video. Given their exposure to digital media culture, they were not offered any formal support in terms of storytelling or use of film and editing software during the project. The only parameter given was, very simply, to make a video in three days based on the exploration of the two terms: camouflage and exposure, in the sense of "exposing visibility. The students were told that, on completion of the video and based on its content and the experiences they had making it they should decide on a product or a task to explore further. The students could, if they wished, continue to use video as a tool in this process. As expected, they already knew or could easily work out how to make a video.
The aim of the task was to explore the use of video as a sketching tool for developing an individual approach to design. The ensuing projects show an experimental and playful attitude, and sensitivity to how much information is needed to highlight some aspect of an object or situation, or to communicate within a given context. It seems that the use of video as a sketching tool to explore the task encourages testing and an experimental approach in real-life situations, with real people. The analysis revealed elements of play on several levels, which was an unpredicted and surprising dimension of the projects. In this article this play element is identified and further explored through theory. The study reflects on

how video, as a creative tool, can put things into play in design education. This is explored through a case study involving concept mapping of the outcomes of a student project, supported by a literature review and semi-structured interviews.

## 2 METHOD

### 2.1 The project

The empirical data for this study comes from original research involving first year students on a master's level course in product design. To begin, the students were divided into groups of five. Their task was to produce a two-minute video during a two-day workshop. As a source of inspiration, the students were introduced to works by three contemporary artists: Liu Bolin's (China) [2, 3] ongoing series of photographs *The Invisible Man*, and photographic works by Ritta Ikonen (Finland) and Karoline Hjort [4] (Norway) entitled *Eyes as big as plates* (2011). Through their work, these artists explore the concepts of camouflage and invisibility in a variety of contexts.

*Figure 1. Left image Eyes as big as plates, Ritta Ikonen and Karoline Hjort. Middle and right image The Invisible man, Liu Bolin [2-4]*

### 2.2 Analysis

In the present study, one of the videos made during this workshop is analyzed from an initial description (context mapping) of the video, which is then further explored by semi-structured interviews with the students [5, 6]. It is argued that the chosen theory is relevant for present purposes because the object of the study (the video) represents elements of play on several levels, as part of the processes of both creation and presentation.

#### *2.2.1 The ideas of Gadamer as a basis for the analysis*

Art puts something "into play", and when you play, something is "at play"[1, 7]. The empirical data from an initial description of the video are discussed in light of Hans Georg Gadamer`s aesthetic theory, and, in particular, the idea of art as play in his book *Truth and Method* [1]. The theory is found to be relevant for this study because the video represents elements of play on multiple levels of the processes of creation and presentation. In view of the dialogue between practice and theory, it will be useful to consider the hermeneutical tradition more closely, as described in particular by Gadamer. "Hermeneutical aesthetics is dialogical in character. It recognizes that practitioner and theoretician share in bringing a subject matter to light and plays down any theory/ practice division in the arts. Interpretation is a means to a work's realization"[8]. Associations with the game hide and seek, which was introduced as part of the students' briefing, can be found in the photo project *Invisible man* by Liu Bolins, further supporting the relevance of play. In the next section, the relevant aspects of play will be elaborated through the analysis of one of the student videos.

## 3 DESCRIPTION OF THE VIDEO

### 3.1 Putting something into play when doing research by video

The video opens with a panning panoramic view from a cantina. A man is walking past the rubbish bins located next to the cleaning station. The design of the bins is subtle, blending into the surroundings. On one of the bins, the video makers have mounted a large sign bearing the word "rubbish", with an orange arrow pointing down into the bin. There is no sound, only a small caption that pops up in one corner with the single word "routine?" This is followed by a frame in which the problem formulation of the task is stated as "How do people react when we challenge the norms of throwing garbage?" This was the students' first experimental test of user/viewer reactions or change in behaviour caused by a new sign, as the first element of putting something in to play when conducting research through video.

### 3.2 Putting something into play in society

The next section of the film shows a rubbish bin of the kind that uses a foot pedal to open the lid. The bin is decorated with a string of LED lights, and it plays music when the lid is opened. Sound is now introduced, and it is the realistic sound of what is happening in the images. This continues through various clips of something being made in a workshop. The camera focuses on the machines and the technical aspects of craftsmanship, with a focus on aesthetics. The students said they wanted to include this because it seemed of value for the viewer to know how things are made, as well as to prove that they had met the specified requirements for the task. As an example, one shot shows a circular sawing blade as it is elevating, which to an imaginative eye might be seen to resemble a rising sun. More and more details of what is being produced are gradually revealed, and we see a sign being produced of a person throwing something up in the air. Finally, we see the finished product: a large rubbish bin has been reimagined as a basket net fitted high on a wall, with the sign of a person throwing something into it. However, the most direct reference to putting something into play emerges in the last part of the film, introduced by a slide bearing the text "reactions?" The images are from an outdoor city environment in the evening; we again see the spectacular pedal bin, but relocated to a path in a city centre park. In the evening dusk, a passer-by is investigating it, and when the lid is opened, the lights come on and music begins to play. Surprisingly, the passer-by picks up the bin and takes it with her. On the soundtrack, we can hear the students' reaction to this: their laughter tells us that they found it humorous and unexpected, relating in this instance to putting something into play *in society*.

### 3.3 Putting something into play by changed behaviour

The students then say let's continue with stage two. This sequence includes music, and shows the rubbish bin as a basket net being installed next to a small kiosk selling doughnuts. A camera is fitted on top of the rubbish bin, looking down into the basket and to the street below. In a style that suggests a music video, we now see different people attempting to throw their rubbish into the basket. The last images show several direct hits straight into the basket. We can hear the sounds of throwing, talking, and people sounding enthusiastic. Caught on the camera from the basket, we can also see a woman filming the installation. In the interview, students commented that passers-by seemed curious, pausing briefly to look. The more playful among them picked up rubbish from the ground and aimed at the basket. This stage explores putting into play in terms of *changed behaviour*, triggered by a product an unexpected context.

*Figure 2. Video stills from student video with basket rubbish bin, 1. MA, 2012/13*

In summary, the video demonstrates the philosophical and reflective aspects of play as activated on three levels: putting something into play when doing *research by video*; putting something into play *in society*; and putting something into play through *altered behaviour*. In the next section, we will consider the relevant aspects of Gadamer`s theory on the playful aspects of making art.

## 4 CONSCIOUS AESTHETICS AND PLAY

### 4.1 Play as practice

The metaphorical use of the term “play” is familiar to us in everyday usage; we say that the light plays on the water surface, or the wind plays with her hair. In this context, backward and forward movement is important for our understanding of play. Gadamer observes that humans play in the same way as nature, which provides a model for art by conducting its play purposelessly, repeatedly, and effortlessly [1]. The freedom in such play is not, however, without risk: indeed, the possibility of failing is a large part of a game’s attraction, as the player is at the mercy of the rules and the situation within the game. Where “to play” is associated with a certain lightness, purposelessness, and lack of seriousness, Gadamer’s analysis of the nature of a game shows otherwise. “The person that does not take the game seriously destroys the game”[1], and to play a game demands full and serious attention if it is to keep its characteristics intact: “What constitutes fair or foul play depends upon a set of pre-understood principles just as what is esteemed excellent in art requires normative expectancies of appraisal” [8]. Art does not usually quietly follow conventions or meet expectations—on the contrary, it proposes other rules to follow and offers different perspectives. “Art’s primary concerns is to present a commentary or an alternative perspective to society”[9]. And whereas Kant attributes a non-purposive rationality to the aesthetic attitude, Gadamer attributes it to the playful process of art practice itself [8].

### 4.2 Play in society

The social boundaries of play rely on an agreed set of rules and time constraints [7]. Furthermore, it includes “a greater attention span and problem-solving abilities” and “understanding of others` feelings intentions and perspectives and social reciprocity” [10, 11]. Gadamer proposes that both conscious aesthetics and play are activities of mediation, acts facilitating what happens in the *in-between* of artist, artwork, and viewer that constitutes the substance of the work. Seen as an analogy to play, it may be considered that the player, the game (rules, co-players, circumstances) and the spectator constitute this mediation. The player is of less importance here because the game is a realization that refers to itself. He maintains that to play and art are not isolated from life, but an independent modus of being. Both the game and art are constituted in the process of being played and practiced. Through the ability of artworks to bring things to mind and to hint at layers of meaning, it functions essentially as a language. Yet Gadamer acknowledges that linguistic means of expression are inadequate to the task of conveying what occurs within an experience of art. Gadamer states that “‘conscious aesthetics can elicit activation on a limited or very broad level regardless of materials or tools used for the creation’” [8].

### 4.3 Play as approach towards new ways of acting

The notion of play as an independent modus of being whose purpose is to be what it is and represent what it does—whether in a play, a musical improvisation, painting, or poetry—is that it needs to be seen, but has its own autonomy. “The game analogy also serves to undermine approaches to art which are exclusively intentional, material and conventional” [8]. This approach supports emancipation from material and craft traditions in aesthetic practice and it opens up for the philosophical and cognitive sides of aesthetic practice. “Such transformative power implies recognizing in a work what was previously understood of a subject-matter, but transformed, as if seen for the first time” [8]. This situation, however, is always moving: according to Gadamer, the life of any such subject matter is one of change and development: “The hermeneutical process claims that through repeated re-working and re-interpretation a subject matter not only accrues more aspects but also, in so doing, they allow that subject-matter to become more fully what it is” [8]. Perspectives of play offer a means of including or even preparing for the unexpected, and of creating change by the altering of rules or conventions. The idea of art as play leads us to the possibility that every artwork can be the starting point for new ways of seeing and acting.


*Figure 3. Putting something into play, play's role in aesthetics and plays role in play*

## 5 REFLECTIONS ON THE PLAY ELEMENT

The video analysis above reveals how a playful and experimental approach to a task can enable students to discover previously unknown resources within themselves, and within the project. Most importantly, as described, the study demonstrates the actions and reflective aspects of play that were found in the project on several levels. Gadamer's descriptions of the characteristics of play as an in-between space, between reality and fiction has opened a fruitful perspective in aesthetic practice. This can contribute with supplementary views on didactic practices within product design studies through surfacing new perspectives from which to act. Furthermore his perspective of *play* as an understanding of something that can challenge our inventiveness within certain frames can open up to the unpredictable. As the students said, the project opened up to the discovering of things that they had not already plotted out or anticipated as interesting for the study. For example, the fact that the first rubbish bin was stolen by the very first person who saw it could not have been predicted, and might easily have diverted the project in another direction. The accidental and unplanned nature of putting something into play is an important aspect of discovering what you don't already know—perhaps one of the most valuable aspects of play, from a designer's point of view.

## 6 REFLECTIONS ON THE USE OF VIDEO

Video is a medium that is used in society and in cultural industries, whether for marketing purposes, documentary journalism, artistic use (such as music videos), or personal and private use. It is non-exclusive and in a sense limitless and, like any other technology, it is constantly changing and adapting. Using video also strongly connects with the visual culture that surrounds the students in their everyday life, as digital technologies constitute a significant part of the language through which we express ourselves. The student projects show an experimental and playful attitude; this might be due to the nature of visual and multimedia language, which offers a range of communicative and expressive facets that appeal to the use of several senses and the imagination. "Imagination helps to provide meaning to experience and understanding to knowledge; it is an apparatus through which people make sense of the world" [12]. The impact of technology on individuals, communities and the artist's role are articulated in an article on new media by Remko Scha:

> Media technologies are super-artworks. They articulate the space of artistic possibilities so explicitly that creation is reduced to choice. A technology is like a score which prescribes the structure of a piece for the greater part, but grants the performer some license. Media artists are performing artist. The composer is the designer of the medium[13].

It seems clear that the use of video as a sketching tool to explore the task encourages testing and experimenting in real-life situations that involved real people.

## 7 IMPLICATIONS FOR DESIGN RESEARCH AND EDUCATION

The aim with the student task was to explore the use of video as a sketching tool for developing individual design approaches. The findings show that the use of video as a sketching tool to explore a design task encourages the students to interact with each other and society in a direct way. The student projects show an experimental and open attitude, and sensitivity to how much information is needed in order to draw attention or to communicate in a given context. The study suggests some implications for design research and education, identifying the play element engendered by the use of the video as a useful part of the creative process. Play as practice, play in society, and play as formation for new ways of acting are the key issues elaborated within play theory and aesthetic research as they relate to the student projects in this article. The theory of aesthetic hermeneutics outlined in this article has its origins in a discussion on art and play, but goes beyond the position of art to look at play as a formation on a more general level. The hermeneutic approach requires one to engage with the object of interest (artwork or person) on the basis that it has something to convey that you don't already know [8]. This paper sheds light on the position of play in the making process, in research, and in the reception stages of a project, and suggests that perspectives of play can usefully be encouraged in design education and in design projects generally. Play offer means of including the unexpected, and of creating change by changing rules or conventions. The unpredicted elements of putting something into play in a given context provide support for discovering things you do not already know.

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# A TRADITIONAL APPROACH TO 3D PRINTING

**Julian LINDLEY, Richard ADAMS, John BEAUFOY and Stephen McGONIGAL**
University of Hertfordshire, United Kingdom

**ABSTRACT**
Since the 1980's Industrial Design has developed beyond the remit of the traditional realisation of the object or product. Design is seen as a user-centred problem identification and solution methodology which can be applied to several contexts or issues. However, there is still a need to be able to realise a manufactured artefact; skills increasingly demanded by industrial design employers. The knowledge of materials and how they are processed into components is paramount in this process. Also, in the last few years the possibilities for rapid prototyping and manufacture through 3D printing machines has become financially possible and creatively opens up new possibilities. Shapes which can now be manufactured were impossible a few years ago. The authors took a pragmatic approach which utilised the possibilities of 3D Printing to help understand the complexity of traditional manufacture through a design and build project. Whereas most student projects conclude with propositions, few are carried through to validation. Although the more engineering based programmes do build and test prototypes, complexities of design for manufacture are usually left unresolved. Students were challenged to design, manufacture and assemble a working model of an alarm clock. Each component has to be designed against an understanding of a material and production process and then prototyped on a 3D Printer. The final product was then assembled from these prototype components. Finally paper concludes that making is an essential part of the design process and that new technologies can enhance this empirical approach.

*Keywords: Design method, construction, manufacture, rapid prototyping*

## 1 INTRODUCTION

This paper outlines how the authors have used the new technologies of rapid prototyping (RP) and 3D printing (3DP) to help students connect the virtual world and real worlds through a design project for industrial design (ID) students. Within this construct (the project), students built on their prior knowledge of design for manufacture (DfM) through component design and product assembly. This also involved negotiating the compromises needed to realise a product through real materials and the processes by which they are manufactured. There was rigour in the realisation of the final working prototypes. Against this backdrop of a disconnection between design in the virtual environment and real manufacture the authors advocate utilising CAD and RP within design for manufacture or production [1].

The paper concludes with a reflection on the value of this project against the learning curve of student experience as training for the product design profession.

## 2 BACKGROUND CONTEXT

The challenge to design and build an alarm clock is an individual project constituting a 15 Credit Module (120 credits undertaken per year) in the first semester of the final year of a three year ID Programme. It builds on prior learning of the design process, a knowledge of manufacturing and the skillbase of CAD (Solidworks CAD Package). Through this project this paper explores, three current issues within design education:

### 2.1 How to integrate the new possibilities of Rapid Prototyping, 3D Printing and additive manufacture (RP) into the curriculum.

This is a complex subject as it originates within industry and includes questions on how these new possibilities will impact on the way we manufacture and consume products. Not only does RP facilitate the creation of objects which were previously impossible to make but it also alters the landscape of production possibilities, shape and quantity. Without tooling costs objects can now realistically be made as one offs and small production quantities rather than needing the economics of scale afforded to mass production. This in turn has posed new questions for designers, those of 'new visual languages', 'new production possibilities' and 'new economic possibilities through one off or mass customisation'. This is acknowledged and explored by Ford and Dean [2]:

*The tool-less manufacturing flexibility of AM (additive manufacture) allows for more personal approaches to production such as mass-customisation, with outputs tailored to an individual's need or desire* [2]

However they go on to note:

*Almost any form imaginable can be reproduced by AM and production issues could potentially be ignored* [2]

This is countered by Valamanesh and Shin[2] who see Digital Fabrication as a tool to replicate and explore complex components:

*Digital fabrication provides realistic opportunities for representing, evaluating and redesigning complicated forms. It extends learning in a digital design environment since designers will be engaged with materials and machine processes similar to industrial production.* [3]

Ford and Dean finally conclude:

*What is clear is that it is not valid for designers to be encouraged to ignore 'traditional' design for manufacture processes at this point in time; they have to be introduced to the opportunities and constraints inherent in all levels of production. Teaching should not be restricted to innovative practice in the application of new technology but all appropriate methods, old and new.* [2].

This paper attempts to connect the value of RP as a new opportunity for detailing design for manufacture.

### 2.2 Virtual and Physical Environments

Although RP generates more physical objects, the process is more aligned to the virtual rather than physical world. Objects are conceived within a 3D CAD virtual space rather than evolved within the workshop with physical models. 3DP emphasises the need to be competent with CAD skills and further alienates student designers from the physical world and traditional design methods. This need to work in and test within the physical environment is critical to both ID within industry and the training for it [4].

*Whilst designing in the 3D digital environment allows for a faster and possibly more fluid process, we still have the need for the real object as seen in the 'real' world……..*

*………This 'hand's on' approach can be used to finalise any design problems that may arrive during the digital environment, one such example is scale or fit.* [4]

There are now instances where students (and professionals) are proposing designs, which can only be realised through RP and do not understand the complexities of production, scale, materials and techniques. Some students have never translated or evolved designs from the virtual CAD environment into realisable objects in the 'real' world. This could lead to a detachment of ID from the manufacturing base where it originated. The business model for design [5] which correctly assumes that ID can, amongst other benefits, deliver value in manufacturing, needs designers who understand the practical as well as the theoretical.

The authors also note that some candidates for degree programmes in design do not come equipped with a natural intuition of how things are made, structures, materials and strengths. We live in a world where a failed product is discarded rather than repaired. People do not take products apart to repair them and a fundamental knowledge is being lost to students (and others). In contrast, the virtual world through the computer is a natural environment to them. They are Digital Natives as defined by the Oxford Dictionary:

*a person born or brought up during the age of digital technology and so familiar with computers and the Internet from an early age* [6]

We are dealing with Generation Z [7] as students do not explore in the real world in the way they are fearless in the virtual world. The project outlined below is an attempt to link the two worlds and re-engage student designers with the third physical dimension.

### 2.3 Dealing with a crowded curriculum.

In many instances projects deal in methodology and design thinking often culminating in design propositions outlining a concept, physical presence and interaction. Although valuable, an understanding of manufacturing detail is being reduced or marginalised. Although Universities have become strong on the breadth of investigation and Design Thinking, students often lack a depth of knowledge, in this instance of detailing for manufacture. The UK Design Council describes this interdependency the T of Design, Figure 1.

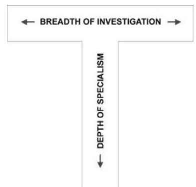


*Figure 1. T shaped Design*

*"The stem of the T is the depth of knowledge in their specialist subject while the horizontal cap of the T represents the breadth – their ability to make their method, skills and thinking work in a different context."* [8]

The project also connects to the Design Councils Double Diamond design process, Figure 2.

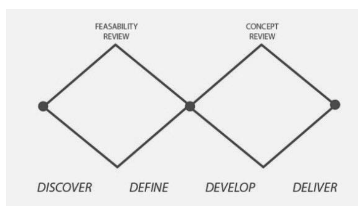


*Figure 2. Design Councils Double Diamond Design Process* [9]

Many design programmes focus on the 'Discover' and 'Define' elements of the process, encouraging imaginative, user-centred solutions to social or product issues. The core of this project is located in the Develop and Deliver phases of the Double Diamond Process. Emphasis is given to the realisation of an assembled product so resolution of manufacturing and assembly details are critical to a successful outcome.

The project outlined below reconnects the physical to the virtual as a process or design methodology. It addresses the points outlined above with particular attention on 2.2 and 2.3. The project explores the interplay between real and virtual, traditional skills and new possibilities. It achieves this by incorporating and valuing 3DP as a mechanism to replicate complex 3D components.

## 3 OUTLINE OF PROJECT

As a final year project it was an opportunity for students to demonstrate the management of a project from initial design responses to the construction of a working prototype. One Learning objective, relating to this paper, was to explore and understand the relationship between the design concept and physical reality, in a design process from sketchbook through to simple 'proof of principal' models and then from detailed CAD models through to working prototypes.

### 3.1 The Brief

The individual task set to final year students was relatively straightforward:

*You are required to design an alarm clock. This is a design and development project, which has a technical bias. The PCB and electronic components are available as part of a kit that should be purchased from the University. You should design an innovative solution to the alarm clock, which will* *enclose the electronics. You will also assemble the PCB for inclusion in a working prototype that demonstrates innovative design, product function and component detail.*

The task was rooted in a traditional aspect of ID, that of encasing technology. The electrical components were given and the only leeway allowed was that the students decided which components would go on a PCB and which could be satellites to it. This immediately introduced an interesting compromise between innovation and practicality. Being too creative would mean significant modification to the board making the product difficult to realise and possibly impair functionality. Leaving the components without change could result in poor user interaction. Students dealt with the external attributes, aesthetics and interface while resolving the internal component layout including design and specification of the case system (parts). With the later they were required to 'print' these on a 3DP machine. The number and size of these parts was defined within the brief; a maximum of six components to be made by RP. This limitation was logistical relating to the number of students and available resources but also taught students to work within limitations. The processes were restricted to Polyjet and Fused Deposition Modelling Technology.

The Brief had defined stages and deliverables as follows:

1. *Concept work including sketch drawings, foam models, CAD models and photorealistic images illustrating at least 3 concept alternative designs, trial printouts of components for evaluation. The designs should be innovative and their style must reflect the intended market. One must be selected for development into a detailed design.*
2. *A document or storyboard demonstrating how the user interacts with the product.*
3. *A fully developed CAD model of your chosen product design communicating the detail design of the enclosure, including PCB location features, button and display interfaces and design for manufacturing details.*
4. *CAD models (of each individual for 3D Printing).*
5. *A working prototype of your chosen design with the PCB assembled into the prototype enclosure.*
6. *High quality visualisation images of your chosen design for presentation.*

## 4 CONTEXT AND PURPOSE

As part of the design process, students were also allowed to experiment with parts prior to obtaining 'sign off' on the final design. This experience was essential in integrating 3DP into their design method. The use of accurate parts informed the design process in a time efficient way. Emphasis was placed on modelling the intricate details in CAD. This demanded resolving the 'minutiae' and was constantly a revelation to students, as it demanded both rigour and investment in time. By contrast, once modelled in CAD, producing 3D objects is 'rapid', hence the earlier term of rapid prototyping for the technology. These parts have to be realistic to a commercial manufacturing process not just replicable with 3DP. The 3D prints were used to emulate high volume manufacturing processes. The project challenged students to detail their components to a quality where the data could be used for production tool manufacture. Once printed, the parts needed to be finished. This required an attention to detail during cleaning, sanding and painting. Once complete, the components were assembled into working prototypes. This final aspect of assembly was important as students realised, through hands-on assembly, how effective or efficient their design detailing has been.

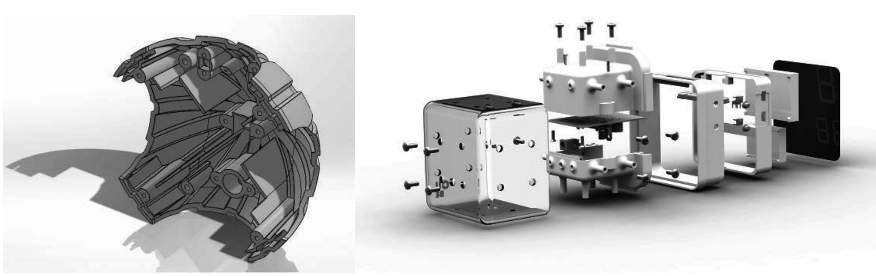

*Figure 3. CAD Models of Components*

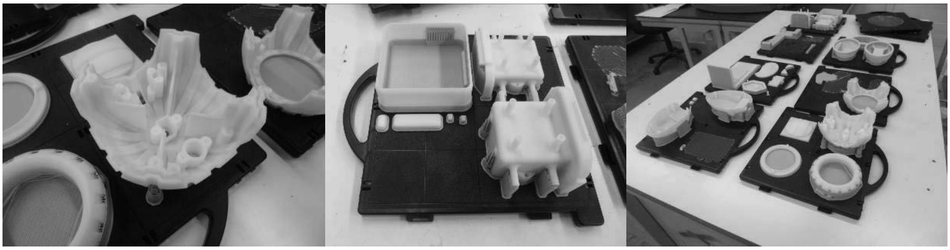

*Figure 4. Printed Components from the RP Machine*

## 5 CONCLUSION AND REFLECTION

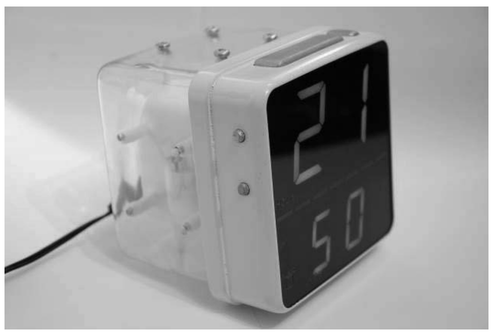


*Figure 5. Example of completed Alarm Clock*

The aim of this project, and the degree programme, is to holistically educate all-round designers, that is those who understand both the breadth and depth of the T Design Model. A key purpose was to get the physical and virtual environments linked in both design process and students understanding of it. With the latter the project also challenged students to understand the complexities of assemblies, particularly plastic parts. This depth of understanding is valuable in a graduate's portfolio when making the transition from education to employment. In this there was not an acceptance that ID is not just clicking a button to print out what was on screen but an understanding of the value of both virtual and physical environments within the design process. Importantly students gained an understanding of when a process or skill is appropriate. They had to justify decisions on design detail before CAD files are 'signed off' by staff and sent to the 3DP machine(s). Within this they had to demonstrate an understanding of how a component is designed for a particular manufacturing process and material, predominantly injection moulded plastic(s). The project bridges the virtual world and real worlds using new technologies relevant to the students (Digital Natives and Generation Z) and the real world contexts, the design of products. particularly advances in 3DP, into the design process. It does not attempt to explore new shape possibilities provided by RP but re-iterates the technology as a realistic replication of traditionally manufactured parts (through, for instance, injection moulding and die-casting). It allows students to quickly and efficiently realise their designs as manufacturable propositions tempering virtual creativity with practical detail. Within this project students also become familiar with the intricacies of prototype manufacture utilising new technologies. One observation we have is that the project may be more appropriate earlier in the programme so the gained knowledge can underpin further work. The value of the project can be summed up by the following student:

*'The alarm clock project was an excellent learning opportunity. The project helped me understand, in detail the process of taking an idea off the page into the computer and then making the working model. The task of taking concept idea and converting it to a CAD model with the capability of being*

*manufactured was an excellent and challenging experience, this design had to not only be faithful to the concept but also house the relative internal electronics and fit together. When the concept was completed on the computer, it gave me the best possible preview of how the product would look in the real world, This said the first time I saw the finished parts come off the 3d printer they were smaller than I had imagined. Because of the scale and size of a product being very difficult to define, prototyping is the best way to complete the link between the design on the computer and the way that it will look in the physical world to me the designer and other people.'* (Michael Hardie, Final Year Student 2014).


## ACKNOWLEDGEMENTS

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Chapter 13

# USING TECHNICAL TOOLS IN DESIGN

# HOW TO EDUCATE FOR CREATIVITY IN CREATIVE TECHNOLOGY?

**Angelika MADER and Edwin DERTIEN**
Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente

**ABSTRACT**
Creative Technology is a new BSc programme at the University of Twente. Its goal is to design novel applications and products to improve daily life of people, with ICT as design material. Applications range from everyday life to health support, from playing and entertainment to serious gaming and socializing, from working and learning to art, while using instruments of stimulation, motivation, or support. The goal of the BSc programme is to give students the skills, methods and tools that enable them to design such products.
A paradigm of Creative Technology is that existing technology has a potential that is not yet fully explored. This potential lies in the novel use and ways of integration of existing technologies into new and innovating applications and products. This perspective is different from classical technical education, and, consequently, requires also a shift of design methods and teaching approaches.
How to stimulate creativity is not a new question. However, it mainly is addressed in other domains. Moreover, most of creativity stimulating techniques aims at different target groups, like children, artists, designers or managers, not technology students. And certainly they are not meant as relevant skills within scientific education.
The contribution of this paper is a structured analysis of our attempts and experiences with five cohorts of students in teaching Creative Technology. We will discuss the implications for the teaching practice of Creative Technology and will outline the possibilities and limitations of our practices for other technology oriented design curricula.

*Keywords: Creativity, teaching methods, tinkering*

## 1 INTRODUCTION

In Creative Technology, a new BSc programme at the University of Twente, novel applications and products to improve daily life of people are developed, with ICT technology as design material. Applications range from everyday life to health support, from playing and entertainment to serious gaming and socializing, from working and learning to art, while using instruments of stimulation, motivation, or support. The goal of the BSc programme is to give students the skills, methods and tools that enable them in the design of these products.
Creative Technology integrates different disciplines, basically technology, design and business. Art is considered as a source of inspiration and a platform for experimentation. A paradigm of Creative Technology is that existing technology has a potential that is not yet fully explored. This potential lies in the novel use and ways of integration of existing technologies into new and innovating applications and products. This perspective is somewhat different from classical technical education, and, consequently, requires also a shift of design methods and teaching approaches.
In the curriculum, project courses play an important role, taking about a third of the time. The classical courses are arranged around the project courses that the knowledge and skills needed for the practical work is available at the right moment. Creativity is a core ingredient here, for the identification of new areas of applications, and also for the way of using technology.
This paper contains an analysis of experiences in teaching. Starting from different activities that characterize the work of a Creative Technology professional and student, we try to distinguish different roles and forms that creativity takes here. Next, we map these to teaching approaches, helping the students to develop creativity. The concepts of creativity (stimulation) discussed here are not new. The contribution of the paper is to put them into the context of Creative Technology, a technical, academic setting.

## 2 CREATIVITY IN CREATIVE TECHNOLOGY

Basic characteristics of creative products are that they are novel and valuable. In the literature these aspects are extensively refined and extended, which. For the purpose of this paper it is sufficient to take these basic characteristics that are our reference point when evaluating students' work. Novelty, for us, is an unexpected element, either in the use of technology or in the application.

As sources of creativity are knowledge, thinking skills and motivation [1]. Also here, more fine grained definitions exist (e.g. [11]). Relevant in the first place is, that these components can be developed, implying that creativity can be taught, which is the consensus in the literature.

Our intention is to be as specific as possible, for the context of Creative Technology, in order to get practical examples and principles. Even if our context is an engineering faculty, we do not have to introduce new creativity concepts in a traditional engineering context as in [4]. The goals and tasks of Creative Technology in themselves are already different from the traditional engineering programmes. Making this explicit, we start with a differentiation of the activities of Creative Technology on a more detailed level. Methods to stimulate creativity will depend on the sort of activity and its specific goals.

The following is a list of tasks of a Creative Technology student and/or professional, that address knowledge and thinking skills:

2.1. The task that Creative Technology does not share with other disciplines it to investigate existing and new technology from the view point of usability in human centred applications. In this line, a habit should be to use material (also) in different ways than it was intended. This requires a different perspective on products and concepts than trained in a classical technology or engineering education. An example for different usage is an old video-recorder, which either can be seen as old video-recorder (traditional perspective, black box view), or as a programmable motor that could possibly be used for an automatic cat feeder[1] (creative technology perspective, understand working principles).

2.2. Material mastery is a basis, where the material is technology, ranging from programming to design tools, from electronics to dynamic system modelling, is only gained by hours of experimenting and exercising, next to basic theory forming. A pure black box view on the building blocks or components is too limited in our context. For both, the adequate use of existing components, and for the exploration of future ones (2.1), understanding the working principles of components is crucial.

2.3. A Creative Technologist should be able to define and extend her/his own tool set, driven by the area of interest, by challenge or by external factors. Working within a defined tool set requires a different kind of creativity for problem solving. One example here is the kinetic artist and engineer Theo Jansen[2], building his sculptures only from PVC. The common solution to a wind-driven vehicle being able to move over a beach would lead to a sail-and-wheel solution. The restriction to only one material can lead to very innovative (and aesthetic) solutions.

2.4. Creative Technologists have to provide building blocks for other designers, who may not be technology experts, but have, e.g., stronger roots in the health domain (for a health support application), or in education (for a learning game). Identifying and constructing new building blocks is an activity in its own, not part of a user-driven design process. In user-driven design, starting from requirements, product ideas are generated and iteratively refined. At some point, ideas are translated to technological solutions, which are taken from the building blocks available for the designer. This translation moment is typically not a moment where new technology is explored. Examples for existing tool sets are developer platforms like MaKey MaKey[3] with a very broad target group ranging from children to artists, or the Sifteo cubes[4], which are for playing games, but also a platform for game developers. A very prominent building block is the Arduino[5], allowing the connection the physical world of sensors and actuators with a PC. Other examples are the Cubelets[6], LilyPad Arduino[7] sets, or littleBits[8]. The common characteristic is

[1] http://cachefly.oreilly.com/make/television/VCR_CatFeeder_FINAL.pdf
[2] http://www.strandbeest.com
[3] http://www.makeymakey.com
[4] http://www.sifteo.com
[5] http://arduino.cc
[6] http://www.modrobotics.com/cubelets
[7] http://lilypadarduino.org

that they are designed by creative engineers to enable other designers to create much more easily new products. For Creative Technology students the development of a toolbox is a typical assignment [6] [10].

2.5. Together with exploiting existing technology, the identification of novel application domains is a prominent goal of Creative Technology. Much more social and cultural skills are relevant here, in addition to the technical ones. A vision on qualities of life, reflection on culture, the ability position oneself in the society, together with an understanding of technological feasibility is needed here.

## 3 HOW TO STIMULATE CREATIVITY

### 3.1 Breaking Patterns

Breaking the patterns of the standard perspective and design approach is a meanwhile well-known technique, that is propagated by, e.g., Design Thinking[9] and Lateral Thinking approaches [2]. These techniques include reversal of an idea, exaggeration, random connections, alienation, scamper [3] (substitute, combine, adapt, modify, put to other use, exaggerate, reverse), etc.

Practically, it means that the paths of well-known strategies get closed, such that new paths have to be explored, leading to novel solutions. This principle can be supported by methods, and be trained. From a teaching point of view we experienced that we have to force students getting out of their comfort zones (which is sometimes appreciated only much later), until they understand the benefit of the approach. Below, we discuss two techniques that we use in more detail.

*Quantitative Idea Generation* In the project course "Living and Working Tomorrow" 100 ideas as combination of two topics (e.g. chair and chocolate) have to be produced within one afternoon. After the first couple of ideas, creating such an amount of ideas is hard work, requiring time and focus. In the following, the lecturer together with the students evaluates the ideas, combines them and distils one resulting idea. Next to driving out of the comfort zone, this method follows the creativity concept "quantity breeds quality". Even years later, the students mentioned this exercise as an eye-opener.

In our courses we use this method for "out-of-the-box" projects and assignments, especially for novel applications as described in 2.5 above.

*Limitation* We work with limitation of the tool box in assignments, as an "in-the-box" creativity activity. Not having the obvious tools has two effects: one is that new solutions have to be found using the available tools, supporting 2.2 and 2.5 above. The other is that the existing tools have to be extensively explored to identify the possibilities the material offers for new solution, which stimulates 2.1 above. Another explanation for increase of creativity is the following: if the design space is large, much of the creative energy is spent on traversing this design space and evaluating different possibilities in order to focus on a certain subspace. In contrast, in the limitation the designer can immediately spend the energy on the construction of a solution. In the following we illustrate the approach with three examples.

The first assignment was to design a drawing program to be used with only a light sensor and the screen (but no keyboard). A user (lecturer) should be able to draw a naive house with it, at least. The toolset for the students was at this point Processing[10], Arduino and a single light sensor (LDR). To our surprise, the results of the assignment, which was seemingly so limited, were very diverse and creative. After a period of complaining about the assignment, the students invented very different ways to identify positions on the screen and select figures to draw. The results were unexpected, concerning the individual solutions, as well as the range of solutions (moving lines in two dimensions, a half black/half white screen to identify in which half the light sensor is, and the iterating this on the half where it was, different versions of (cascading) grey scale menus etc).

As contrast, the second assignment (in another year), an "out-of-the-box" representative, was to make a digital/physical music instruments, also with Processing and Arduino, but unlimited in the choice of sensors, or kind of instrument, and realization of the sound. The music instrument assignment seemed to allow for much more creativity, a more artistic object to make and not being limited by technology to be used. Some nice results were achieved such as beautifully engineered laser-cut knob-boxes, but

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[8] http://littlebits.cc/
[9] http://en.wikipedia.org/wiki/Design_thinking
[10] http://processing.org

mainly unsurprising straightforward solutions were designed, not comparably as creative as in the drawing example. Despite the larger space of possibilities, the overall result was weaker.

The third example is a video-sequence split in single frames that had to be connected to a sensor in a meaningful way. Also in this limited setting very creative solutions were designed. Examples here, were a tomato soup being parted like the Red Sea, which was detected by two distance sensors, (from a film scene[11]), a bubble gum bubble video, where the bubble gum blew up depending on the force with which the user was blowing on a piezo sensor, or a wheel put in motion, sensed by a potentiometer, triggering the light intensity of a bike light in the video.

Next to the creativity stimulating aspect of the assignments, the examples show that by the choice of the assignment and tool set the domains to explore can be set: for the drawing program a solution required an in-depth analysis of the possibilities of a light sensor, and a solution to be constructed in the software domain. The video-and-sensor assignment gave the technical solution, but the exploration was here more on the conceptual level, i.e. what is a "meaningful" combination of video content and sensor input.

### 3.2 Choice of the Toolset

In the end, we want to support a certain quality in creativity of novel applications. A way to achieve such a quality is provided by methods, and approaches and examples discussed here could be part of a method. The role of tools is to support methods. However, most discussion is on tools, much less on methods, and even less on quality. Starting our analysis and discussion of tools we also want to recall the observation that good students can be creative with bad tool sets, but bad students still have lousy results with good tool sets. In short, a tool set is always secondary to a method. Even if a well chosen tool set can stimulate, it cannot substitute a method.

In [9], [8] elaborated lists of properties of good tool sets are discussed, which do hold not only for software, but also for technology in a broader sense. The lists include low threshold, high ceiling, wide walls, many paths and many styles, combinability of tools, etc. While we agree on each aspect mentioned, we do not believe that all aspects can be realized in one tool set, and certainly not for a beginner. Instead, we suggest an incremental expansion of tools.

For a beginner, a limited number of components offers a lower threshold, that allows to explore its components sufficiently. A huge toolbox may be intimidating. Our beginners get Processing and the Arduino board and a limited set of electronic components (breadboard, wire, resistors, LED[12]) as toolkit, as in many other places. The basic skills with these environments are taught in a classical course (Programming and Physical Computing). Students use the tools also in project courses. A laser cutter and small 3D printer (makerbot) are available in the lab as tools students learn to use on the fly. Experience showed that for most of their projects on this level this tool set is sufficient.

In the course of the study programme the toolset is extended, by electronic components taught in different courses (Introduction to Electrical Engineering, Sensors, Control Systems), and by a more powerful programming environment, Open Frameworks[13]. Different courses add other tools to the tool set as well, for example the course on interactive visualization uses Blender[14] and Unity[15] as tools.

As discussed also in 3.1, a small toolset and a limited assignment stimulates 2.2, material mastery: if a solution has to be found with very little material, the students have to explore very well the possibilities of the material. The technical skills to extend the personal tool set, 2.3., are taught in more classical courses. The stimulation for creativity here also comes in by, e.g., project work, where the product idea of a group needs solutions outside the current toolbox. In contrast, it seems that, e.g., in [8] only “outside-the-box” creativity, as in 2.5, is considered when talking about toolsets. Then, other kinds of approaches and methods are relevant, such as tinkering, which will be discussed in the following section.

### 3.3 Stimulating Tinkering

Tinkering is a mindset, a method or a habit, it is a playful bottom-up way to explore technology and its possible applications. Concerning the Creative Technology tasks above, it contributes to material

[11] http://www.imdb.com/title/tt0315327/
[12] http://www.scintilla.utwente.nl/assets/stores/protobox_quickref.pdf
[13] http://openframeworks.cc
[14] http://blender.org
[15] http://unity3d.com

mastery 2.2, use of technology in novel contexts 2.1, and novel applications 2.5. On an academic level its benefits are training in the loop of identifying new questions, designing experiments to answer the questions, observing, interpreting the results, and deriving a new question to investigate.
Tinkering is not an approach that comes “naturally” in our educations[16]. Even for our Creative Technology students having already tinkering experiences it is not the approach they would choose first to explore new material. In an extra-curricular workshop on wearable technology, where the relevant material was available, like Lilypad sets and lots of extra material, the students did not start exploration of the material. They applied the usual top-down approach, “inventing” some project to do, and then getting frustrated, because the material did not allow for the precise realisation of their ideas. We conclude from that that tinkering is something that has to be taught, or at least stimulated.
There are many toolsets that have potential to stimulate tinkering. Most people have tinkering experiences from playing with toys like LEGO[17]. However, even in the LEGO series a distinction can be made between sets for building mainly one space-ship with detailed step-by-step instruction (which can potentially kill tinkering attitude - of course the parts can be used differently) or sets (Creator and Inventor series) aimed at tinkering. One conclusion here is that while a toolset can hamper or stimulate tinkering, it is the mindset, method and environment that really trigger the playful exploration.
Many of the recent (technical) toolkits such as the littleBits or Cubelets have children as target group, or people with little knowledge in technology. Such toolkits may have a value in the very beginning of our programme, but are quickly too limited for our context. Eventually students should be able to turn anything (the world) into their toolset. A great example is the tinkering workshop described in [5] where literally any type of electronic toy is used as system component. One of the vital *skills* in tinkering is expanding the own toolset with enough types of “glue” (fluid experimentation - easy to connect, see below). Making connections on a mechanical level (sometimes there is the need for a universal connection kit[18]) or at an electronic level using an Arduino as electronic glue. Considering the academic approaches to tinkering, the choice of toolset should not be limited to (technical) construction, concepts can also be material for tinkering, or tools from design. In a number of project courses also moodboards, personas, scenarios and storyboards are used as toolset in order to try out and test user aspects of designs.
In [8] three core principles necessary for a (technical) toolset to stimulate tinkering are elaborated: immediate feedback (see the result, see the process), fluid experimentation (easy to get started, easy to connect) and open exploration (variety of materials, variety of genres).
We identified a number of additional aspects necessary for facilitating tinkering that have been found vital during courses in the programme where students had to realize or construct something. These aspects address the environment and context next to properties of the toolset components: accessibility, availability and visibility, which are elaborated in the following.
Accessibility means, e.g., that tools are in the same lab, the process or software tools do not have a steep learning curve, many examples and best practices can be found and easily shared, software easily installed, that there are enough licenses. Availability means, e.g., that the student are allowed to operate a laser cutter themselves, or ask the ever-present lab manager, the machine is dedicated for student projects, nothing else, or, for software, there are enough licences. Visibility means, that students see, e.g. the laser cutter working and cutting every day, they see the results of their fellow students who used the relevant tools. We illustrate these aspects by three examples below.
The first example is the laser cutter: While we have a well equipped workshop located in the same building (availability, but accessibility with the effort of going there, and no visibility), students only started building physical devices when we stationed a laser cutter in the lab (more effortless accessibility, and visibility). It took one full year before a method (untaught by lecturers) of designing plywood boxes and shapes entered the “toolset” of the students, passed through by some pioneering students (visibility).
The second example is the electronic toolkit: during the first years of the programme we supplied the students with all the necessary electronic materials (accessibility, but availability groupwise only). In later years, the students had to acquire their own toolkits[12]. Availability was increased, as the students

[16] http://www.ted.com/talks/ken_robinson_says_schools_kill_creativity.html
[17] http://lego.com
[18] http://fffff.at/free-universal-construction-kit/

could use their sets at any moment. Also visibility improved, as all students had most of the time their toolkits lying around doing some projects with them. In the end, besides the savings on buying equipment and organizing, the students improved on getting to know the material and, eventually, the tinkering process.

The third example is software tools, where mainly open source, multi platform tools have been chosen. Availability here includes easy distribution and deployment, the software tools run on the own laptop, they can be used any time or place. Accessibility here is that there are (often) no steep learning curves, many tutorials and examples are online. Visibility here includes, that many examples are provided in lectures and online, and work by fellow students.

Further criteria for designing context of tinkering are elaborated in [8], that perfectly meet our experience: emphasize process over product, set themes - not challenges, highlight diverse examples, tinker with space, encourage engagement with people, not just materials, pose questions instead of giving answers, combine diving in with stepping back.

Summarizing, tinkering is a mindset that has to be learnt. Toolsets can stimulate tinkering, where the properties of the components play a role, but also the environment and context.

## 4 CONCLUSION

Our challenge is the education for creativity in the academic, technical context of Creative Technology. In this paper we identified typical tasks of a Creative Technologist that require creativity, bridging between technology and the design of user-oriented, novel products. As means to stimulate creativity we discuss methods, assignments and tool sets, which, in the end, are not independent of each other. The approaches and aspects suggested are illustrated by examples from our teaching experience.

As method behind assignments we discussed breaking of patterns, which is well known from various creative thinking approaches, specifically quantitative idea generation and limitation. Our contribution here is the translation to specific assignments, and an understanding of, e.g., how the kind of limitation, in technology or concept, effects the design space to be explored, the creativity needed and the goals achieved.

We observe that most existing toolkits are developed and designed for children and artists, not for academic needs. The scope of such toolkits is too small, when we want to bring students so far to recognize the whole world as source for designing their own toolkit. But even if existing toolkits are too limited, the design principles or supporting activities, especially those of tinkerability, are more general. They can also be applied in our context, requiring translation steps and extensions.

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# A DESIGN PROCESS FOR CREATIVE TECHNOLOGY

**Angelika MADER[1] and Wouter EGGINK[2]**
[1]Creative Technology, Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente
[2]Industrial Design Engineering, Faculty of Engineering Technology, University of Twente

**ABSTRACT**
Creative Technology is a new bachelor programme at the University of Twente. Goal of Creative Technology is to design products and applications that improve the quality of daily life in its manifold aspects, building on Information and Communication Technology (ICT). The application domains range from recreation to work, from entertainment to learning and from health to art. A paradigm of Creative Technology is to make use of existing technology in novel combinations –in contrast to developing new technology.
In this paper we identify and elaborate the Design Methods of Creative Technology in a consistent overview. On one side, the focus on human daily life suggests that user centred design approaches from Industrial Design and Interaction Design are relevant for Creative Technology. On the other side, the development of prototypes will make use of "classical" engineering design principles. Between these areas of design is a field that is not covered by other disciplines: the exploration of the potential of existing ICT technology, focussing on applicability for the user. To foster this process, our design method is a balanced combination of Divergence-Convergence and Spiral models of design practice.
The purpose of this model is mainly for education. However, for Creative Technology as a multi-disciplinary field, it is also relevant to position itself in contrast to the neighbouring disciplines, which in our context are Industrial Design Engineering and ICT.

*Keywords: Design Methods, Design Process, Creativity, Smart Technology, New Media*

## 1 INTRODUCTION

Creative Technology is a new bachelor programme at the University of Twente. It is also a design discipline on a multidisciplinary basis. Its goal is to develop new and innovative products, applications and services. The designed products are for human usage that improves quality of life in all its different facets, in work and recreation, in health and entertainment, in learning or in art. The design material is technology, ranging from new media to smart technology, using videos and sound, internet, all kinds of programmable platforms, sensors and actuators. One core paradigm is that the potential of existing technology is not yet fully explored and Creative Technology tries to tap from this potential.
Creative Technology is a relatively new discipline that is still in the process of being defined. Making design methods explicit is one corner stone in the definition of the field.
Creative Technology has overlap with a number of established design disciplines, such as Industrial Design, Human-Media Interaction, Graphic Design, Interaction Design, Engineering Design, and more. Accordingly, Creative Technology also integrates design steps and methods from these overlapping disciplines. In the curriculum the variety of methods is reflected by the expertise of the lecturers, who are also rooted in different disciplines. In the project oriented education environment [1] students learn about design methods in a series of integrated project courses that form about a third of the study load. The other courses focus on knowledge and skills in specific domains, such as programming, graphic design, electrical engineering, business and more.
The goal of this paper is to arrange the set of relevant design methods in a coherent structure while emphasizing the parts and steps that are specific to Creative Technology. The result is (a concept of) a design method, built on observations from project courses within the curriculum and methods adapted from the related disciplines. The benefit of explicating a design method is manifold. For students the design method can serve as guideline in their design processes, for planning, implementation and also for documentation of projects. It also provides clear intermediate points for feedback and evaluation

which are important in an educational setting. From the point of view of course design, we notice that different project courses emphasize different phases or aspects of the design process. The positioning of each project course within a larger perspective on design methods allows to develop a more complete and consistent perspective on design in our programme, and also supports fine-tuning of existing content. New lecturers come, in most cases, from one of the (mono) disciplines relevant for our programme. For them, understanding the role of their expertise and design methods within an overall picture of Creative Technology is essential to develop courses adjusted to the programme. Next, embedded in a technical faculty, we continuously have to explain what Creative Technology is, what it can achieve, and, especially, to what extent its methods differ from the well-known engineering approaches. Finally, the definition of Creative Technology as a discipline is an ongoing process. The work presented here is therefore also meant to provide a reference point in the discussion.

## 2 A CREATIVE TECHNOLOGY DESIGN PROCESS

The design process of Creative Technology that we suggest is illustrated in figure 1. On the highest level it consists of four phases; Ideation, Specification, Realisation and Evaluation. Each phase starts and ends with a defined set of (intermediate) results. Before we go into the details of the four phases, we want to elaborate on a few existing classical approaches that provide key elements for our method.

### 2.1 Divergence and Convergence Models

A classical model for creative design processes consists of a divergence phase, followed by a convergence phase, described already by Jones [2] in 1970. In the divergence phase the design space is opened up and defined. The breadth of the design space is typically determined by a number of factors: lateral thinking techniques allow to shift the perspective on the starting question and foster the creativity of the designer, but also her experience and the richness of her cultural background can open the view on “unexpected” solution domains. The converging phase can be described as the process to reduce the design space, until a certain solution is reached. Each reduction of the design space is a design decision based on the requirements and available knowledge. However, many design decisions have to be taken on the basis of incomplete knowledge. Therefore the experience of the designer, her preferences and also her openness to take risks, shape the solution space. A classical model including these phases is the one of Roozenburg and Eekels; “divergence and convergence in the innovation process” [3, 4]. Also in Saffer's book on interaction design [5] a sequence of divergent and convergent phases is explained. In our Design Method divergence and convergence is integrated in the phases of ideation, specification and realisation. Before and after each phase lies a defined set of items, which form natural caesuras within the process (one exception will be elaborated below). Each set of items is a starting point for a divergent sub-process or an endpoint for a convergent sub-process, or both.

### 2.2 Spiral Models

The main argument for spiral models is an analysis of the design steps that design professionals take in their processes. The sequence of steps shows a variation that does not allow for claiming a logical order [4]. They all share however, the components of problem understanding and definition, project planning, idea generation and evaluation. Spiral models are related to the nested problem solving of Wieringa [6, 7] in the sense that each design problem unfolds a sequence of questions that is specific to the starting problem and the context. In nested problem solving, the interwovenness of design questions and knowledge questions is emphasized, which guide along an individual path in the design process. A design question (e.g. “how to design a defrobnicator?”) raises subsequently a knowledge question (“what is the state of art in the design of defrobnicators and related products?”). A knowledge question (“does a cover from smart material improve the user experience of the product?”) raises a design question (“how to design an experiment with which the knowledge question can be evaluated?”), et cetera. A design method based on a spiral model is the Eindhoven Transformational Design Process [8] pictured in figure 2. In this process, all design steps are interconnected and can be traversed in any suitable order, where each step includes a reflection phase. It is for our context a very relevant reference, as the design goals and design material of the educational programme of Industrial Design in Eindhoven are closer to Creative Technology than most other programmes. Whereas we agree on the ingredients of this design process, we feel the need for a more structured one, with more defined intermediate points that give a grasp on the educational process. In this aspect we are oriented towards beginners in design who are best suited with more guidance, rather than experts [9].

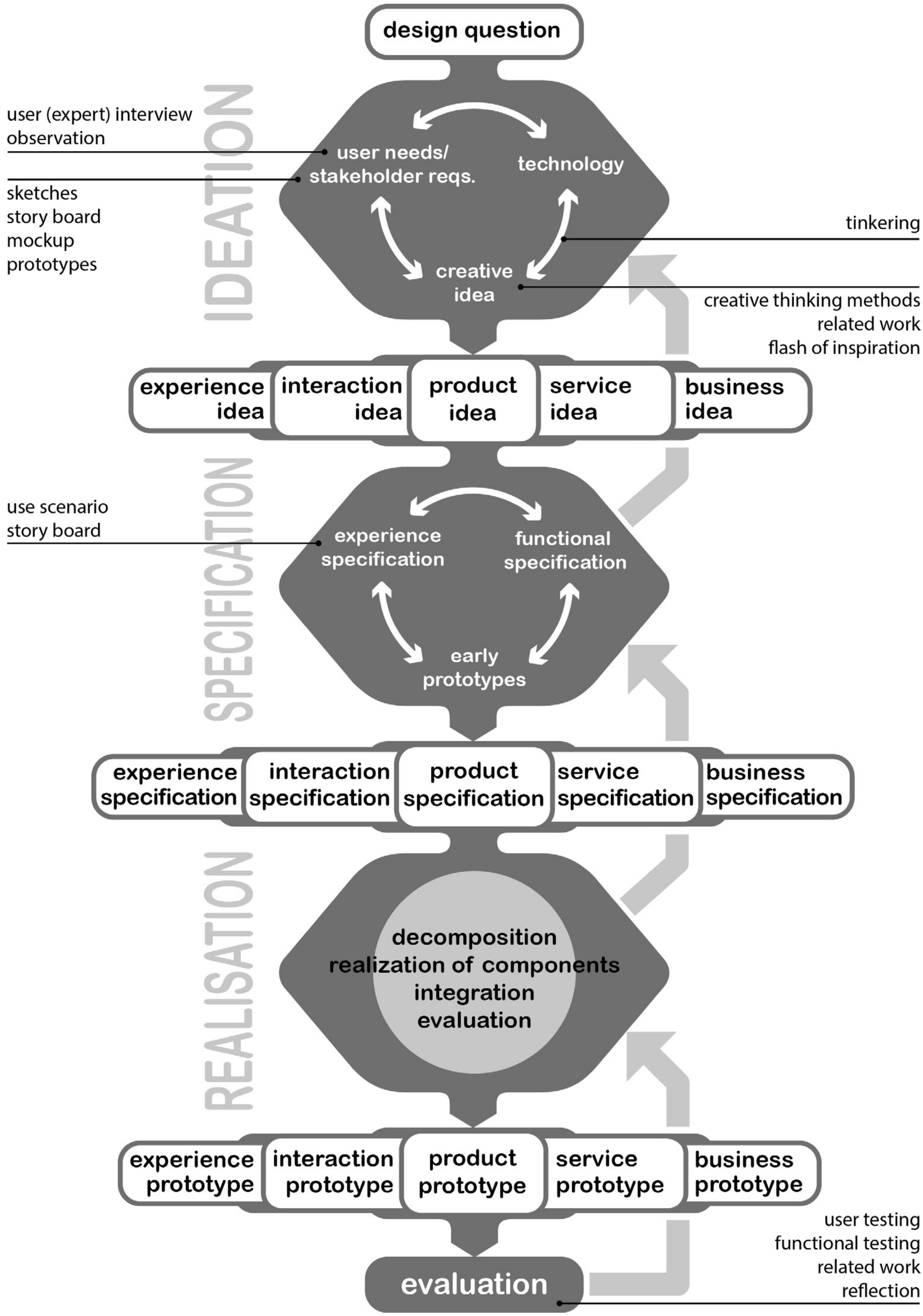


*Figure 1. A Creative Technology Design Process*

In our design method the spiral concept is reflected within each of the phases of Ideation and Specification. Within these phases the elements and their connecting arrows can be regarded as specific instances of the elements in the reflective, transformative design process [Figure 2, left].


*Figure 2. The Eindhoven Reflective, Transformative Design process (left) and two views of the "counting blocks" prototypes by Jelle Dijkstra [10,11]*

## 3 THE CREATIVE TECHNOLOGY METHOD

In the following we will describe the four phases of our design method in more detail. As an illustrating example we take the *counting blocks* bachelor project of Jelle Dijkstra [Figure 2].

### 3.1 Ideation Phase

Starting point of a Creative Technology design process may be a design question in form of a product idea, an order from a client, or a creative inspiration, similar as in related design disciplines. Specific for Creative Technology is that technology can be a starting point or motivating force in the ideation phase. The process that starts with technology is called tinkering, and has as goal to identify novel applications for existing or new technology [12]. In this sense the approach bridges between technology and user needs, which is in this form not provided by any other discipline.

The spiral form of the ideation phase as suggested here shares the problem definition, acquisition of relevant information and idea generation with similar approaches. Creative ideas may have many sources. They may come from a flash of inspiration, or be the result of one of the lateral thinking techniques as by de Bono [13] and others. With this work we share the conviction that creativity can be trained to a certain level, and is more often the result of hard work than the kiss of the muse.

Another source of inspiration is related work (which plays different roles in the different phases). Adaption of existing solutions may be on a conceptual level (e.g. transferring an Amazon-like book recommendation system to a physical book store, where lights signal a client that a book may be interesting to her), or on a technical level (e.g. by using an energy monitoring system, that should raise awareness for energy leaks in one's home, as a monitoring system of the energy consumption of an elderly person, indicating that the elderly is active and well, or not.) Evaluating early ideas with clients or users applies similar techniques as other user centred design techniques, using mock-ups, sketches, user scenarios or story boards. Interviews with clients, users or user experts characterize the needs, describe the problem setting and provide requirements. Result of the Ideation Phase is a (more) elaborated project idea, together with the problem requirements. Ideas on experience, interaction, as well as a service and business model are also part of the result.

In our illustrating example of a bachelor project, the initial design question of the student was to equip a well proven toy with educational content, in contrast to designing an educational toy. During the ideation phase the student visited a Montessori school and a day care (user needs, requirements, investigation of present (educational) toys), and came up with lists of popular toys and lists of possible educational contents. These actions together formed the divergent part of the ideation phase. In the convergent phase he decided for a user group (children in pre-school age), an educational content (counting abilities), and a toy (building blocks). This then defined the transition point to the following specification phase.

### 3.2 Specification Phase

Characteristic for the specification phase is that a number of prototypes are used to explore the design space, and that a short evaluation and feedback loop is applied. Functionality influences the user experience, and demands on the user experience may require change of the functionality. These causalities are evaluated by using prototypes, with users, or possibly by the designer herself. Prototypes are subsequently discarded, improved or (partially) merged into new prototypes. The evaluation may also lead to a new functional specification, in its turn leading to a new prototype.

The large number of prototypes built and evaluated is a major difference from the Engineering Design approach, where typically one prototype is built and improved until the final design is reached. Also the kind of prototypes is different: as the user experience is a driving factor here, prototypes are often reduced to single or few aspects of the overall future product that is responsible for a certain kind of experience. The distinguishing characteristics with respect to Industrial Design is the interplay between technology and user experience. According to the different design material, the prototypes in Creative Technology often contain electronic components, such as microcontrollers, and show some dynamic behaviour.

In our illustrating example of a bachelor project, the functionality of the counting blocks should be that they can count their colour matching neighbours. To make early prototypes, displays of mobile phones were used to show the numbers. A user test at the day care showed that the children could read large numbers on the displays well. A functional requirement was that neighbouring blocks can communicate with each other. A coil construction was designed, where coils in neighbouring blocks can allow data transfer, if they are positioned in the correct way. To support the correct way of positioning blocks (user experience), magnets were added to the blocks in such a way that they snap in the correct position. Also the light colour had to be changeable, such that only neighbouring blocks of the same colour group together. It was decided to change the colour by a knock or fast movement.

### 3.3 Realisation Phase

When a product specification is given, we can follow in the realisation phase the proven methods of engineering design, that are characterized by decomposition of the start specification, realisation of the components, integration of the components and evaluation. Prominent design models including these steps are the Waterfall Model and the V-Model. These models are typically linear, allowing for backtracking in case of “wrong” decisions. Phases of divergence and convergence are not explicitly elaborated, and might be identified in high abstraction level in shape of the entire phase. Evaluation within this phase has to validate whether the end product meets the subsequent specifications. Not yet included in the model are the realisation processes of the business and service specifications.

In our example, the student took a decomposition step first, analysing the components necessary for the realisation, like communication, connection, CPU, powering, charging, tilt detection et cetera. For each part he came up with a list of possible solutions (which is in fact also a divergence phase), and selected a subset consistent with the requirements. Next, he realised the components, by buying (electronics), building (casing, coils), and programming (protocol for communication via the coils). Eventually six prototypes were built as shown in figure 2.

### 3.4 Evaluation Phase

Evaluation may address a number of aspects. Functional testing is typically already included in the realisation phase, but could also have a place here, and may address earlier functional requirements. Certainly, it has to be evaluated whether all the original requirements identified in the ideation phase are met. User testing is the most obvious method to verify whether the decisions taken satisfy the user requirements and facilitate the experience intended. Related work at this point has the function to position the own result in the context of existing work. Finally, reflection is the basis for personal and academic progress. Here, we do not have the “classical” student reflection in mind [“If we had started earlier we would have been able to finish the product in time.”], but a personal attempt to make implicit decisions explicit and to reconsider one’s own (implicit) standards, as elaborated by Visscher-Voerman and Procee [14].

In our example, the student finally observed children from pre-school playing with the blocks. He could confirm that the children talked about the numbers, but played more with the colour changing possibilities. They also used the toys as mere building blocks, which was either one intention of the concept: building a toy with educational benefits, rather than building an educational toy.

## 4 DISCUSSION & CONCLUSION

Our design process model combines the concept of divergence and convergence with a cyclic concept. Convergence at a small number of defined intermediate points is useful in an educational context. They separate the overall trajectory in more comprehensible units than a global divergence-convergence approach or an overall cyclic model. Intermediate goals structure the process, allow for more specified steps in the planning, and also define feedback moments. The cyclic elements take the variety of paths in the design process into account, that are driven by the nested questions of problem solving and are specific to the character of each individual design project and the designers involved.

Relevant for us is to distinguish our process from classical Engineering Design in the emphasis on divergent and convergent phases, as well as on the circular process steps. Whereas both may play a role in Engineering Design, the emphasis there lies more on a linear process with possibilities for backtracking. Moreover, the design space exploration using multiple prototypes that are evaluated against a user experience is not present in the classical Engineering Design process. On the other hand, the distinguishing factor from Industrial Design is the continuous interplay between technology and requirements, especially for user experience.

Although we present just one example for illustration, the design method we suggest builds on observations of multiple project courses given in the curriculum, integrating methods from related design disciplines. We ordered the set of identified methods in a coherent way, and give possible explanations substantiating of the kind and arrangement of the design steps. From a scientific point of view we have treated the steps of observation, ordering and explanation, the latter as first step to the forming of a theory. As remarked rightly by Dorst [9] for the development of a design method, theory forming and evaluation would also be obligatory steps in a proper scientific treatment of the subject. At this state however, we take a pragmatic point of view, and hope that the explication of a Creative Technology design method gives the opportunity for discussion and development, which is needed as a basis for further steps in the definition of the discipline.

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# USING DESIGN HEURISTICS IN IDEA GENERATION: DOES IT TAKE EXPERTISE TO BENEFIT?

**Markus VOß[1], Thorsten SAUER[2] and Hulusi BOZKURT[1]**
[1]DHBW Baden-Wuerttemberg Cooperative State University Mannheim
[2]DHBW Baden-Wuerttemberg Cooperative State University Ravensburg

**ABSTRACT**
This paper presents a study that examines how well-known methods for idea generation can be advantageously combined. It investigates *Method 6-3-5,* a group technique for six developers who successively refine three initial ideas under tight time constraints (within five minutes per round). In the conducted experiments, this commonly used brainwriting technique was complemented with a set of design heuristics that should help the participants to abstract the problem and should guide them to potential solutions.
The study (with $N = 88$ participants in total) compares first and third year B.Eng. students in a Mechanical Engineering programme with young professionals holding more than one year working experience. For evaluating the solutions that the participants generated, metrics were employed that measured the variety and the quantity of the ideas. The paper also analyses if more experience permits engineers to overcome the 'fixation' to an initial design.

*Keywords: Creativity, conceptual design, design heuristics, brainwriting techniques, design fixation*

## 1 INTRODUCTION

During the last decades research changed perception on creativity. It is no longer seen as an unchangeable ability that fortune blindly favours individuals with. Today it is assumed that everyone has a creative potential that can be developed and that the role of education is to facilitate the exploration of it [1].

### 1.1 Brainwriting techniques

Method 6-3-5 is a commonly used brainwriting technique, cf. [2]. Based on the concept of Osborn's brainstorming, this team-based method aims at quickly exploring the solution space and producing a great number of ideas (up to 108 ideas in only 30 minutes). As in other creativity techniques 'freewheeling is welcomed, quantity is wanted, combinations and improvements are sought, criticism ruled out' during application [3].

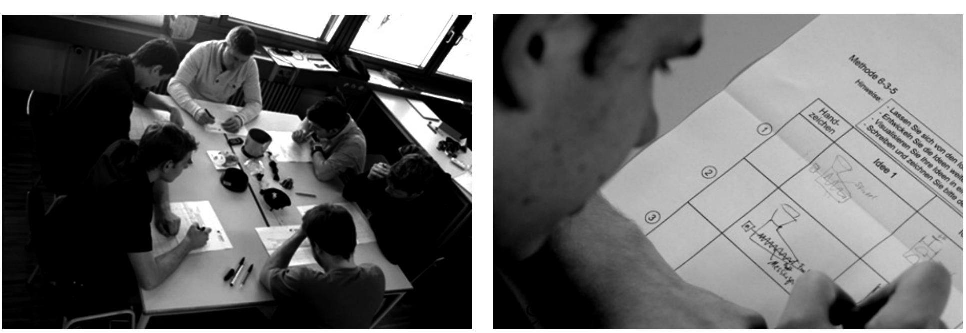



*Figure 1. Brainwriting session*

The technique involves <u>six</u> participants (who are optionally supervised by a moderator), cf. *Figure 1*. Per round, each participant is asked to generate <u>three</u> ideas. The ideas are put down on a worksheet in form of short text and sketches. After five minutes the worksheet is passed on to the next participant. The technique encourages the participants to refine the ideas of others, but they also can choose to interrupt that chain of ideas and add complete new thoughts. After six rounds the group has produced a total of up to 108 ideas in just half an hour.

### 1.2 Design heuristics

Design heuristics are intended to 'drop mental ballast' and liberate developers from the confinement to existing solutions. They should serve as 'cognitive shortcuts that encourage exploration of novel directions' [4]. In our study we provided some of the participants with Osborn's checklist [3] which includes nine generic mechanisms of inventive idea generation [5], namely

- substitute
- combine
- adapt
- magnify
- modify
- put to another use
- eliminate
- re-arrange
- reverse,

also known under the mnemonic SCAMMPERR.

## 2 RESEARCH QUESTIONS

In research on design expertise, the relationship between expertise and creativity is related to be a close one [6]. In our study on idea generation techniques, we have been particularly interested in

- differences in the results of novice and experienced designers
- benefits from using design heuristics (for each these study groups)

## 3 EVALUATION METHOD

In order to explore the effects of design expertise and design heuristics on the solution space generated with help of brainwriting techniques, a series of factorial experiments was conducted. The analysis of the obtained data was based on a specifically developed set of metrics.

### 3.1 Participants

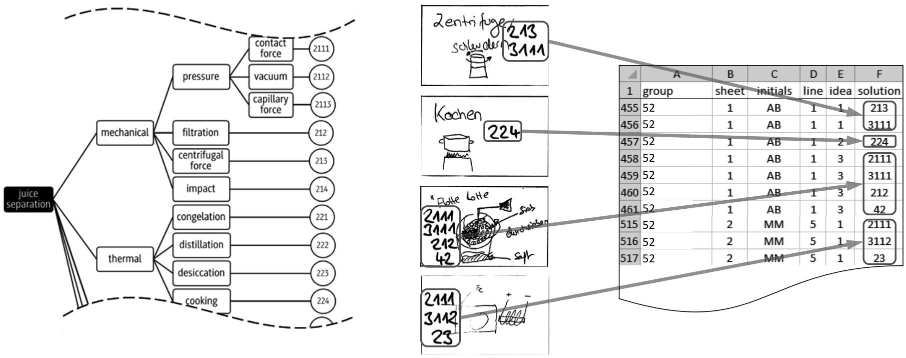
In total, $N = 88$ engineering design students participated in the experiments. The participants have been selected with respect to their formal degree of expertise: The *novices* are undergraduate students enrolled in the first ($N = 55$) and third ($N = 20$) year of a B.Eng. programme in Mechanical Engineering. The more experienced designers are *young professionals* ($N = 13$) who worked between one and three years in industry before taking up part-time studies in an M.Eng. programme. The participants worked in teams with a nominal group size of six.

### 3.2 Task

In our experiments we confronted the participants with a typical open-ended design problem. We asked all participants to find novel solutions for extracting juice from citrus fruits. The group of young professionals has been more experienced (not only in general terms but also) in that specific field of knowledge since they analysed (benchmarking, functional analysis, Design of Experiments, use tests, cost analysis) a citrus press in their M.Eng. course on Product Development methods.

### 3.3 Data analysis

All solutions that the groups have generated in the experiment were systematically classified, see *Figure 2a)*. Two evaluators inspected every completed field on the worksheet and coded them according to the classification system, like shown in *Figure 2b)*. The total number of solutions contained in the analysed worksheets was 2924.



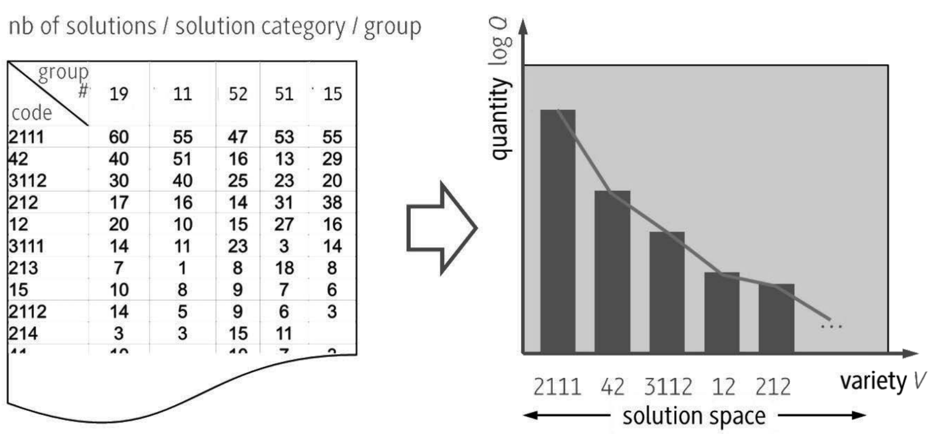

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | group | sheet | initials | line | idea | solution |
| 455 | 52 | 1 | AB | 1 | 1 | 213 |
| 456 | 52 | 1 | AB | 1 | 1 | 3111 |
| 457 | 52 | 1 | AB | 1 | 2 | 224 |
| 458 | 52 | 1 | AB | 1 | 3 | 2111 |
| 459 | 52 | 1 | AB | 1 | 3 | 3111 |
| 460 | 52 | 1 | AB | 1 | 3 | 212 |
| 461 | 52 | 1 | AB | 1 | 3 | 42 |
| 515 | 52 | 2 | MM | 5 | 1 | 2111 |
| 516 | 52 | 2 | MM | 5 | 1 | 3112 |
| 517 | 52 | 2 | MM | 5 | 1 | 23 |

(a) (b)

*Figure 2. (a) Excerpt from the classification system, (b) coding of solutions*

### 3.4 Metrics

The coded solutions then were analysed in a Pivot table. For measuring the effectiveness of idea generation empirically, we mainly used two objective metrics [7]: one describes how *diverse* solutions are and another how *many* there are. The *variety V* of the generated solution space was assessed by counting the number of non-redundant ideas, i.e. the number of solution categories addressed by a group. Within each solution category we counted how many times a group has used an idea on their worksheets *(quantity Q)*. The diagram in *Figure 3* arranges the solution categories in decreasing order.




| code \ group # | 19 | 11 | 52 | 51 | 15 |
|---|---|---|---|---|---|
| 2111 | 60 | 55 | 47 | 53 | 55 |
| 42 | 40 | 51 | 16 | 13 | 29 |
| 3112 | 30 | 40 | 25 | 23 | 20 |
| 212 | 17 | 16 | 14 | 31 | 38 |
| 12 | 20 | 10 | 15 | 27 | 16 |
| 3111 | 14 | 11 | 23 | 3 | 14 |
| 213 | 7 | 1 | 8 | 18 | 8 |
| 15 | 10 | 8 | 9 | 7 | 6 |
| 2112 | 14 | 5 | 9 | 6 | 3 |
| 214 | 3 | 3 | 15 | 11 | |

*Figure 3. Procedure*

In a regression analysis, we found that the function $Q(V)$ is nearly exponentially distributed, see *Figure 4*:

$$Q(V) = ae^{bV}, \tag{1}$$

with an elevated coefficient of determination $R^2 > 0.89 \ldots 0.98$ for all groups.

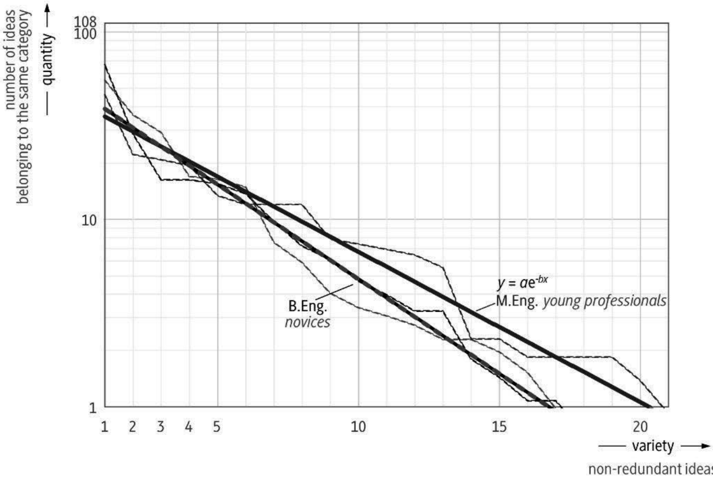



*Figure 4. Regression analysis*

The intersection of this frequency distribution with the axes furnishes two characteristic values:

- the corrected number of non-redundant ideas $V(Q = 1) = -(\ln a)\ / b$ (2)
- the corrected quantity in which the most frequent idea has been used $Q(V = 1) = ae^{b}$ (3)

## 4 RESULTS

It might astonish at first sight that novices produce more ideas than their more experienced peers. But we found evidence that novice group's repeat well-known solutions without developing alternatives, see *Figure 5*. Out of the 108 fields in total, one extreme group (#11) used their 'favourite idea' $Q(V = 1) = 80$ times, while they only developed $V(Q = 1) = 12$ different ideas. This phenomenon is also called design fixation [8].

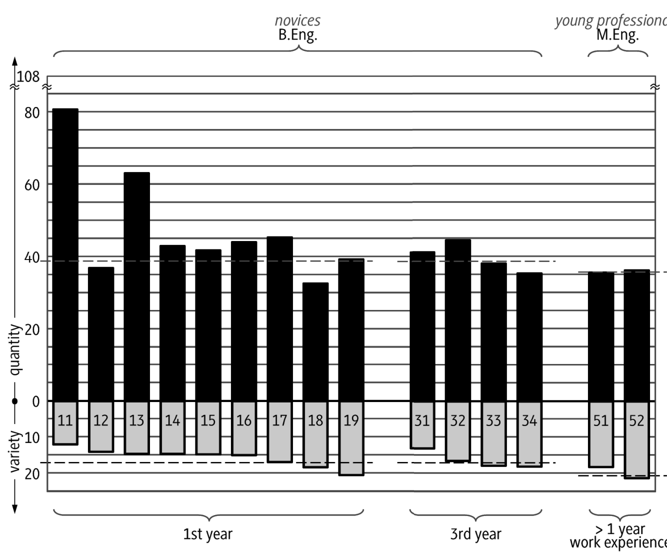



*Figure 5. Variety and quantity of ideas for different levels of expertise*

The difference in the respective average of first and third year B.Eng. students was 'microscopic', cf. *Table 1*. Thus, *novices* generated a variety of $V(Q = 1) \approx 17$ non-redundant ideas per working group and used their most 'popular' idea in $Q(V = 1) \approx 39$ fields of a worksheet. By gaining more experience, designers seem to lose their fixation to standard solutions. The variety of solutions found by the *young professionals* raises slightly to an average of $V(Q = 1) \approx 20$ non-redundant ideas. This makes also drop the quantity of identical basic ideas to $Q(V = 1) \approx 35$ in average per group.

*Table 1. Average values.*

| level of expertise | | $V(Q = 1)$ non-redundant ideas | $Q(V = 1)$ most frequent idea |
|---|---|---|---|
| novices *B.Eng.* | *1st year* | **16.79** | **39.0** |
| | *3rd year* | **16.78** | **38.9** |
| young professionals *M.Eng.* | | **20.4** | **35.4** |

In the experiments, the additional use of heuristics makes productivity of *novices* drop but has no influence on their 'wealth' of ideas. Out of the 108 fields that a group had to complete, the novices filled around 96. The worksheets of groups that we asked to work with heuristics were less complete. They only managed to create 77 solution fields *(Figure 6a)*. In the same time, the number of non-redundant ideas was nearly not affected (around 20 solutions with and without heuristics), see *Figure 6b)*.

The *young professionals* group is a little more 'productive' (completing 101 fields). Interestingly, there is almost no difference if young professionals were using heuristics or not, *(Figure 6a)*. But the number of non-redundant ideas is reduced by half if this group uses heuristics (46 to 23), see *Figure 6b)*.

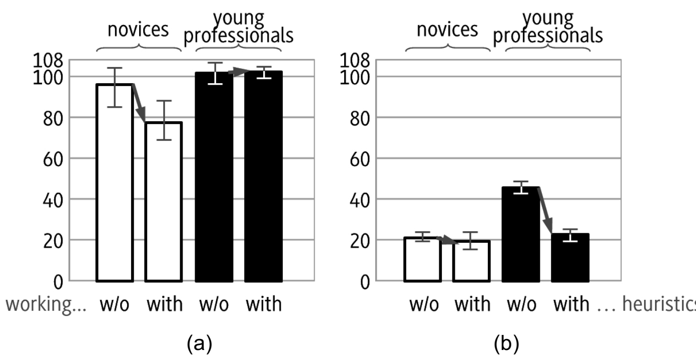



*Figure 6. Number of (a) completed fields and (b) non redundant-ideas per group (minimum, average and maximum values indicated)*

In order to understand if participants were 'building on the ideas of others' [9], we examined the brainwriting worksheets in detail and analysed how long an initial idea was refined during a session. Therefore we counted the number of rounds (= lines on the worksheet) of continuous work on an initial idea *(Figure 7)*. In average, *novice* groups work over 4 rounds on an initial idea and there is almost no difference whether they were using heuristics or not. But the results of the *young professionals* vary: When using heuristics, the *young professionals* were working significantly longer on an initial idea (rise from 2.5 to 4.9 lines). In combination with the results shown in *Figure 6,* it can be assumed that experienced participants of a brainwriting session (young professionals) changed their behaviour if they are supported by heuristics.

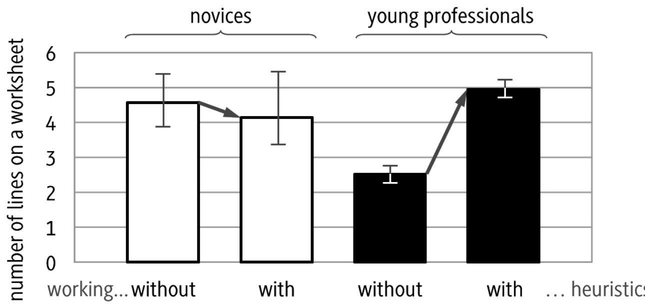



*Figure 7. Continuous work on an initial idea (minimum, average and maximum values indicated)*

## 5 DISCUSSION AND CONCLUSION

In this paper, we describe a detailed procedure for analysing a solution space based on a problem-specific classification system that decomposes ideas to partial solutions. This enables to measure the variety and quantity of partial solutions. In future studies, studying the combination of partial solutions might bring further insights.

In our study, we were interested in how design expertise effects idea generation with brainwriting techniques. With the experiments we can confirm the findings of other authors stating that *novices* tend to develop concepts which are 'often either replications of, or minor changes to existing concepts' [4]. Compared to novices, the young professionals group created more *diverse* solutions, but *less in quantity*.

Combining brainwriting techniques with *design heuristics* globally attenuated quantitative idea production. But we found a qualitative improvement in the work of young professionals who, contrary to novices, intensified their interaction by building their solutions on those of others. Thus, we answer the question asked in the title of this paper with 'yes': It also takes some experience to benefit from support with design heuristics.

In future research, it also might be interesting to enlarge the spectrum of expertise of the study group, comparing novices not only to advanced beginners but also to competent problem solvers, experts, masters and even visionaries [10] on one side and to persons totally unrelated to engineering design on the other.

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# FACILITATING STUDENTS' DESIGN SENSITIVITY AND CREATIVITY IN DESIGN DETAILING AND MATERIALISATION THROUGH PHYSICAL MODELS AND PROTOTYPES

**Siti Salwa ISA, Andre LIEM and Bjørn BAGGERUD**
Department of Product Design, Norwegian University of Science and Technology

**ABSTRACT**
With respect to structured design processes, physical models are developed with the intention to give additional insight to the analytical, explorative, creative, detailing and materialisation design activities of the designer. In design education, the final two activities are often underemphasised in a structured design process, as educators tend to teach students to focus on defining problems and developing creative design solution at a strategic and conceptual level. Modes of representation in the form of holistic physical models are then developed to complement the understanding on these early stages of design activities. The neglect of detailing and materialisation activities, because of time constraints, increased accessibility to other modes of presentation such as CAD, or students´ misconceptions that creative exploration should only take place in the idea and conceptualisation stages of the design process, is a phenomenon, which need to be seriously addressed in design education. Furthermore, the student designer is not always aware of 3-D representation tools which are suited to facilitate such a divergent and creative process in this detailing and materialisation stage. The aim of this article is to propose a systematic approach for design students to select the most appropriate models and prototypes to facilitate divergence and creativity in the detailing and materialisation stages of the designing process.

*Keywords: Models and prototypes, Detailing and Materialisation, Design Education*

## 1 INTRODUCTION

Modelmaking and prototyping are focal areas in Industrial Design education. Every Industrial Design student should have basic skills in model making to explore form, composition and functionality from idea development to detail design. Being involved in modelmaking at an early stage, may enhance the "young designer's" critical understanding of the design process and experience with experimentation and design decision making [1]. To avoid misconception during the materialisation and detailing stages in the design process, new learning concepts and tools are needed to assist design educators in transferring knowledge and skills to design students. Educators and students in Industrial Design should re-think the functionality of 3D physical models as these tools are not only useful in for generating design ideas, but in conceptualising and materialising the detailing aspects of the final design. Aiming to inculcate a sense of urgency among design students to develop final design concepts with high quality of detailing, this paper will proposes several learning concepts on how to use 3D visualisation, as a tool to communicate among Industrial Designers and to achieve better understanding on how physical models and prototypes can be used during detail designing and materialisation stages. In design education, Charlesworth [2] says physical modelling has always been used by design students to develop and communicate their ideas. However, the introduction of 3D computer modelling software has significantly replaced certain hands-on visualisation approaches, which were characterised by a slow, dirty and difficult process of making, into a quick and clean virtual way of designing and prototyping. On a more careful note, Charlesworth [2] added that the designer may face greater challenges and limitations when using CAD in the materialisation and realisation stages than originally anticipated . This is attributed to the lack of good information from educators to design students about the purpose and the effectiveness of models and prototypes and how these tools may contribute to enhancing students´ creativity and sensitivity.

## 2 HOW MODELS AND PROTOTYPES FACILITATE DIFFERENT MODES OF LEARNING AND TEACHING

Due to globalisation trends and pressures on "mature and new economies" which requires highly skilled and knowledgeable human resources, educator and learners should be more reflective and critical towards which methods of learning should be promoted in which contexts. They should create a common understanding of "what" should be taught and "what" should be explored and experimented in first instance. Liem [3] emphasized that today's Industrial Design educator must adopt a radically different and creative teaching strategy to adapt to a paradigm shift in the formation of design education, from a traditional and vocational emphasis on "making" to a broader interdisciplinary focus on "design thinking". He considering a more practical and operational perspective in higher design education the following approaches in design teaching and learning should be examined: (1) Systematic and Process-oriented Design Teaching, (2) Reflective and Experiential Learning, and (3) Learning through a Master-Apprentice relationship in design [3].

In systematic and process-oriented design teaching, students are taught a strict development process of problems solving [4]. The central concept in such a process, are the systematic and deterministic ways of designing, inspired by a structured design engineering process. Here the main problem is partitioned into smaller sub-problems accompanied by sub-processes, which can be solved using problem-solving methods [5]. Although interaction, divergence and convergence take place in a strict development process, students tend to perceive it as a kind of "recipe" for designing. With respect to models and prototypes, modes of representation are then specifically dedicated to certain stages of the process. For example, a sketch model out of foam is being created to complement the idea generation stages, whereas a non-functional design model is created to supplement the final design. This somehow prescriptive approach on how to use models to support the designing activity may restrict to some extent creative thinking. It may naturally lead to a more straight forward and rather narrow exploration of design details and ways of materialisation.

Moreover, a systematic but linear design approach makes students unable to carry forward and integrate learnings from one stage to the next. They find it difficult to revisit some earlier design decisions, which might qualitatively improve the design [6]. From this perspective, the authors argue for a more constructionist reflection-in-action approach as a reaction to the rational problem-solving philosophy [7]. As design problems are unique and difficult to generalize, designers' or developers' actions and efforts, should focus on reflective and conjectural conversations with the situation in order to reinterpret and improve the problem as a whole. Methods applied by the designer are to be based on acquired knowledge, experience, and reasoning. In terms of representation and exploration, such an approach in designing and design learning advocates the use of a broader spectrum of modelmaking and prototyping methods and tools, also for detailing and materialisation.

Learning through Master-Apprentice relationships in design has its roots in the hermeneutic ways of reasoning. Here, the central challenge for the master and apprentice is to gain a sustained and increasing understanding of the designed product, its contexts, values, and functions until the both have decided that saturation has been reached [8]. As the potential solutions and the choices faced are practically infinite, the design apprentice must, with the help of the master, reduce variety by establishing a direct understanding among its objectives, processes and solution [9]. Hereby, the master´ designer's personal experience and intrinsic knowledge base are invaluable. Complementary, such a Master-Apprentice constellation, demands a research-based learning approach, where the "apprentice" is encouraged to learn from the "master" and have direct access to the latest knowledge and ideas from the "master". In return, the "master" can assign the students to assist him with creating and experimenting *(Modelmaking and prototyping)* to find new knowledge.

## 3 CREATIVITY IN THE DESIGN PROCESS

Various literature studies support the fact that designers use their creativity in developing a wide variety of physical models based on their intuition and experience. According to Viswanathan and Linsey [10] there is a limitation as how to teach creativity to designers. However, Hasirci and Demirkan [11], claim that creativity can be stimulated by teaching students creativity methods and techniques. Loewy [12], mentioned that the most important design discoveries took place during modelmaking practices with various materials in the detailing and refinement stages of the design process. He suggested that students should be given a freedom to develop their own design methods and tools by encouraging them to experiment with materials and constructions without being worried of making mistakes or exceeding deadlines.

By appropriately using physical models in the design process, it can help the designers to evaluate and fine-tune their final design as well as confirm certain critical requirements. In this context, Viswanathan and Linsey's [10] experiment also demonstrated that creating appropriate physical prototypes enhances the designer's innovative and creative capabilities at a micro-level of idea generation and conceptualisation, which may contribute to a more elaborate materialisation and detailing design activities. Complementary, Steffany [1] also found in her research that models are one of the greatest assets in inspiring, developing and improving student's awareness concerning aesthetics, construction, durability, proportion, scale, sensory, quality or any other educational dimension.

The use of creativity techniques in design processes can effectively assists designers´ materialisation and detailing activities. Similarly as in industry, Hsiao and Chou [13] proposes a creativity-driven design process to be used in design education. According to them an appropriate product design process comprises of a complete set of integrated creative, analytical and development activities. Additionally, they developed a creativity method based on the natural sensuous ability of human beings, known as "Sensuous Association Method (SAM)", which has the main purpose to produce creative ideas to facilitate designer's individual association and stimulation [13]. Hasirci and Demirkan [11] also proposed a creative design process, adapted from the five stages (5R's) of the Sensational Thinking model of O'Neill and Shallcross. Complementary, Green [14] designed a Major Project Development Model (MPD Model), comprising of a seven stage process, which has been implemented in industrial design teaching at the University of New South Wales. (Table 1)

*Table 1. Three creative methods with its proposed operation adapted from Hsiao et al [13], Hasirci and Demirkan [11], and Green [14]*

| **Sensuous Association Method (SAM)** Hsao et al. (2008) | | **Adapted 5R's Sensational Thinking Model of O'Neill and Shallcross** Hasirci and Demirkan (2010) | |
|---|---|---|---|
| **Human Senses** | **Operation** | **5 R's stages** | **Operation** |
| ***Looking:*** Look at the involved things | Gather group of team designer in informative and creative environment | ***Readiness:*** activity that being open on possibilities | Imagery, ideas searching and observation. |
| ***Thinking :*** Think about origins and evolutionary trends | ***Discussions begins :*** thinking logically about the origins and evolutionary trends of target product | ***Reception :*** To experience fully and observe with all the sense | imagination, generation, idea selection, refinement evident |
| ***Comparing:*** Compare what you look and what you think | ***SAM :*** participant has to compare their associations with information/pictures observation and contemplation | ***Reflection:*** Remembering activity and allowing time for internal interaction | evaluation, idea development, enriching, expanding discovery |
| ***Describing:*** Describe your mental image | must be described in a sensuous phrase, and written down by the recorder. | ***Revelation :*** Focusing and pattern recognition. | develop and enhance the idea |
| ***Stimulation :*** designer's creative inspiration is increased through interaction | members' interactions will stimulate each other's creative inspirations in a highly conducive environments. | ***Recreation :*** To determine full contents and express it by various methods, such as drawing | final representation for missing parts, finishes. |

| **Major Project Development Model (MPD Model)** Green (2007) | |
|---|---|
| **Phase of MPD** | **Operation** |
| ***Product Planning (PP):*** determine a new product idea | Literature search , Benchmarking, SWOT analysis, |
| ***Task clarification (TC):*** negotiating brief with the client | Objectives-tree method, Function analysis |
| ***Concept Generation (CG):*** creative design concepts | Brainstorming, Concept selection, Morphological |
| ***Evaluation and Refinement (ER) :*** analytical and creative tasks are evaluated | House of Quality , Design by drawing, CAD, Design review |
| ***Detailed Design (DD) :*** developing and validating concept | CAD , Value Engineering, Robust design |
| ***Communication of Results (CR) :*** Communicate detail concept to client via 2D / 3D media | Design drawings, Renderings, Prototypes |
| ***Preparation for Production (PP) :*** determine the needs of product production. | Revised cost visibility, statistical process control, Fault tree analysis, CAD |

In Table 1, three creative design methods were mapped against several stages of the designing process as well as their innate human activities. More specifically, different types of operational activities supporting the SAM and MPD model /methods are then reflected upon how each human activity embraces certain creative methods. A literature survey has shown that these three creative methods have contributed to insights on the role of complex of models and prototypes in facilitating creativity and synthesis through out all stages of the designing processes, especially with respect to detailing and materialisation [11,13,14].

According to Jones [15] the creative design process comprises of three essential stages: analysis, synthesis and evaluation. The process can be described as breaking the problem into pieces, putting the pieces together in a new way and testing it to discover the consequences of putting new arrangement into practice. Figure 1, which shows the creativity based design process adapted from Jones [15], indicates that "Transformation" and "Convergence" happens at the three stages. In the transformation and convergence stages, the detailing and materialisation processes are integrated with Green's model for measuring complexity of projects and Welch's theoretical and empirical codes for problem solving in design process. The contribution of Green [16] to the model is more focused towards Industrial Design practice where ten categories of assessment determine certain learning objectives that are essential for Industrial Design students to develop their sensitivity and creativity with respect to materialisation and detailing. Meanwhile, Welch´s [17] proposed coding scheme for evaluating student's problem solving and designing skills through three dimensional modelling shows ample methods and tools, which are available for students use when modelling, improving and building a solution as well as evaluating it.

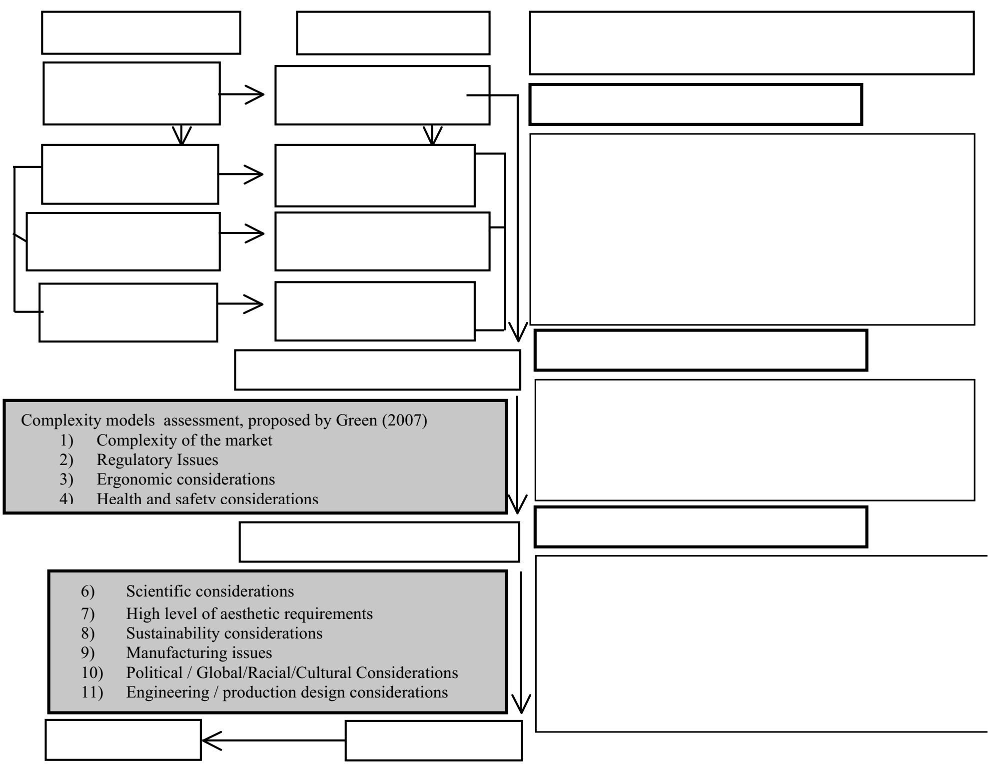


*Figure 1. Creative based design processes during convergent and transforming stages. Adapted from Jones [15], Welch [16] and Green [17].*

## 4 DISCUSSION

The use of prototypes and models will help students in broadening their thinking processes and make them conscientious that divergent, convergent and reflective design practices should not be overlooked in these final stages of designing. It is therefore encouraged that students allocate extra time and effort to explore the creative space through physical models and prototypes during the materialisation and detailing stage instead of focussing too much on final presentations. This requires design educators to emphasis more on methods, processes and tools in their teachings with respect to detailing and materialisation. These processes, methods and tools, whether cognitive or visually explicit in nature, should encourage analytical, creative and generative ways of thinking.

Limited research has been conducted concerning selecting the right type of models and prototypes to be applied during the design process, especially with respect to materialisation and detailing stages. As a result, design educators often overlook the importance to train students to select suitable methodologies to develop physical models to facilitate choosing appropriate materials, developing technical constructions and confirming final finishes [1]. However, few approaches were proposed by various researchers to construct physical model to facilitate the design process. As proposed by Michaelraj [18], Hannah et al [19] and Steffanny [1], the taxonomy of physical models is one of the approaches that supports both educators and students in respectively their teaching and learning practices. With respect to creative methods and processes outlined in Table 1 and Figure 1, Michaelraj [18] described various purposes and applications of physical prototypes which support learning, communication and integration. Furthermore, Hannah *et al* [19] indicates the need for this taxonomy to formalise milestones in the design process and guide designers in selecting and identifying the appropriate prototypes in specific design scenarios. In short, the "Taxonomy Physical Model" by Michaelraj [18] and Hannah et al [19] can be used as a roadmap to examine appropriate methods and processes for developing detail design solutions and materialisation design activities.

Numerous research has shown that design students who use physical model as a creativity tool in every stages of their design process will gain a clearer understanding of form, function and construction compared to student who did not do it. However, there is a tendency, that students in Industrial Design prefer to develop their designs mainly through sketches, renderings and 3D computer models as an alternative to being hands-on engaged through for example modelmaking and prototyping at the final design stages. They believe that constructing models can be expensive and time consuming and therefore should only be used when needed. They do not see that exploring the solution space through appropriate models and prototypes will actually enhance their cognitive design capabilities, especially during final stages, where design confirmations are required. Literature reviews have indicated that compared to using CAD tools, increased model making and prototyping practices in the detail designing and materialisation stages enhances students′ sensitivity towards the generation of well- defined and thought through quality products. However, this requires a creativity approach towards integrating modelmaking and prototyping practices in the product design process. The "Sensuous Association Method ", "Adapted 5R's Sensational Thinking Model of O'Neill and Shallcross", as well as Welch's "Theoretical and Empirical Codes to describe Designing and Making" in the "Major Project Development Model", are methods which can be suggested to educators to facilitate students creativity and synthesis skills in the early idea generation, as well as detailing and materialisation stages of the design process.

Goldshmidt and Rodgers [17] highlighted that educators should teach their students structured and systematic design processes when solving ill-defined problems. However, these processes should not impose rigid ways of thinking, but stimulate exploration and reflection through iterative, divergent and convergent modes of designing throughout all stages of the design process. Given this context, educators are challenged to assist students to plan their design process in such a way as to allow sufficient time for detailing, while in the meantime highlighting the importance of it for creating quality designs. However, the concern is that once an emphasis is placed on detailing and materialisation work, students tend to converge towards concrete solutions quite early in the design process.

## 5 CONCLUSION

Results have indicated that compared to using CAD tools, increased model making and prototyping practices in the detail designing and materialisation stages enhances students′ sensitivity towards the generation of well- defined and thought through quality products. Hereby, educators are challenged to assist students to plan their design process in such a way as to allow sufficient time for detailing, as well as to highlight the importance of it for creating "award-winning" products. However, the concern is that once the studio teacher has pre-empted the importance of detailing and materialisation work, students tend to converge towards concrete solutions quite early in the design process. Given this educational dilemma, the author proposes an intensive cognitive and descriptive approach for analysing design problems and generating solutions, followed by a strict process of idea generation and conceptualisation. However this, strict development process should be compensated through a more extended divergence and convergence process in the detailing and materialisation stages using models and prototypes, complemented by a "master" and "apprenticeship" interactions between student and faculty to facilitate inquiry.

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# 3D PRINTING: IMPROVING CREATIVITY AND DIGITAL-TO-PHYSICAL RELATIONSHIPS IN CAD TEACHING

**Jeff BARRIE**
University of Bath, United Kingdom

**ABSTRACT**
Some undergraduate design and engineering students can struggle with many of the abstract concepts of producing a CAD (Computer Aided Design) model. Features often have to be formed linearly and logically to build up the design intent of an object. Bosses need to be 'added', 'extruded' or 'protruded'. Holes need to 'cut', or 'cored' out of a shape. Some of these 'building' principles are similar to the construction of a 3D hand-drawn sketch, where features are added or subtracted to form the final shape. Both 3D sketching and 3D CAD modelling practices require good understanding and interpretation of 2D orthogonal views to understand 3D geometry. Difficulty arises when parts come together to form assemblies and relationships within a separate environment. Additional difficulty is found when students have to convert 3D objects back into 2D draft drawings. The 2D to 3D and 3D to 2D relationships can be somewhat confusing-but they are vital for engineering design and drawing. To improve the understanding of CAD practice, 3D printed objects have been introduced to enhance teaching activities. The introduction of 3D printed models has been well received, with better student engagement and an understanding of a 3D object within digital and physical space. Students are now inspired to expand their modelling knowledge as now, what was a simple vehicle modelling assignment, has developed into a creative student challenge where the end goal is a physical 3D-printed model of their own CAD work.

*Keywords: Computer Aided Design (CAD), 3D Printing, Creativity*

## 1 INTRODUCTION

Proficiency in CAD is an important skill for a designer or engineer. The aim of introducing first year Mechanical Engineering students to CAD is that they will be able to carry out simple design tasks using the software. At the same time, these students are introduced to design processes and visual thinking, producing and interpreting engineering drawings as well as freehand engineering sketches. These activities relate directly to the design projects students will be undertaking in their studies as well as their future careers. Within the first semester CAD skills and design processes/visual thinking are unrelated-separated into different teaching units.

All this is part of the first formative years of a Mechanical Engineering student; however the entry requirements of many engineering degree programmes focus heavily on Mathematics and Physics qualifications. It is only in some more design-orientated courses would one find requirements for D&T (Design & Technology) or Art & Design. Therefore, many engineering students start their academic career with little or no qualifications in drawing, visual thinking and design process. This is despite several pieces of research that indicate skills in visual thinking and spatial awareness contribute to career success in Engineering [1][2].

This is why our Mechanical Engineering students have to start with the basics, producing 2D orthogonal engineering drawings with drawing boards, interpreted from 3D views. After that, they produce 3D isometric views interpreted from 2D orthogonal views, progressing into perspective drawing and freehand sketching.

Equally, students are introduced to CAD from the basics; they learn how to build a part using features, progressing into assemblies using parts, exploded views and 2D drafting. The main learning outcome of these classes is to carry out simple design tasks.

Despite being two separate teaching activities; there is some crossover between drawing 3D objects by hand and using CAD. For example, there is the geometry building technique-in which students draw construction boxes and add or cut geometry away to form a 3D shape (Fig 1.).

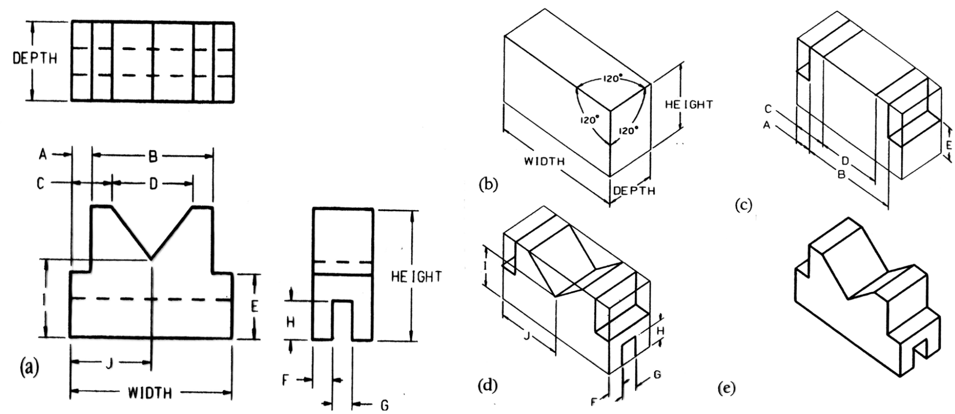


*Figure 1. Isometric geometry building from orthographic drawing [3]*

This is very similar to the process of adding or subtracting features on a model in CAD. In both cases, geometry and dimensions are defined by orthographic projections. An isometric projection is built from the dimensions defined in the three principle iso views. Equally, 3D geometry is defined from 2D sketches and their respective geometry and dimensions in CAD.

Further crossover is apparent in assessment. For example, students in the sketching classes need to produce 2D engineering drawings from 3D views. They also need to sketch 3D isometric views from 2D orthographics. Finally, they represent an isometric or perspective view of exploded assembly. All of these sketching activities utilise physical artefacts. Students in the CAD classes are required to produce a 3D CAD assembly by producing 3D parts from 2D engineering drawings. They ultimately need to represent the 2D CAD assembly as a 2D engineering drawing and exploded views. Physical artefacts have not been used-until now.

## 2 3D CAD 'AND' 3D SKETCHING-THE PROBLEM

As two separately taught activities, CAD and sketching have a major crossover when it comes to student learning outcomes-and that is acquirement of spatial awareness. Students who struggle with sketching practices can also struggle with CAD. This is because both drawing and CAD involve 'graphic ideation' [4] and involve 'mentally rotating and manipulating images' [5]. This lack of spatial awareness seems to be common with international students [6] and can be evident in female students [1] but is slowly becoming not so un-common in many home and EU students coming into University with little background in drawing and 3D visualization-attributed perhaps to less sports and craft activities in secondary education [1]. This apparent lack of creativity, special awareness and making skills is why the traditional network of subjects associated with Mechanical Engineering; STEM (Science, Technology, Engineering & Maths) is currently being re-branded STEMA in the UK and STEAM in the US, with the inclusion of Art&Design.

Another problem is that some students do not make the association between engineering drawing practice drawn by hand and that drawn by computer. In the second semester, students are required to use their acquired skills in producing 2D manufacturing drawings for a prototype-designed in CAD. The drawings are expected to use third-angle projection, correct dimensioning and relevant sections but some students struggle with this. Having CAD and sketching as two separate activities in semester one does not help this learning outcome.

Equally, when it comes to building the prototype-some students struggle to interpret the drawing-quickly realizing that designing a prototype in CAD and physically building it accurately is a challenge. After all, making mistakes and understanding how the prototype is made and operates is a key learning objective of this particular exercise.

## 3 BRINGING CAD TO LIFE-3D PRINTING

Having observed students struggling with spatial awareness as well as part and assembly construction in CAD classes, it was proposed to introduce physical teaching aids to assist the students. Within the teaching sessions, students use in-built, step-by-step CAD tutorials as well as challenging exercises to build up proficiency. The students are assessed by creating parts of a toy car in CAD (Fig 2.), interpreting from 2D orthogonal views, creating an assembly and then producing a 2D assembly draft drawing and exploded view.

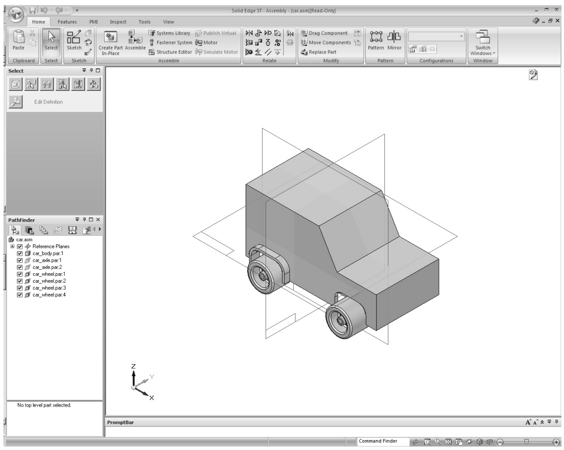

*Figure 2. CAD assembly model of toy car*

At the time, the department had newly acquired desktop FDM (Fused Deposition Modelling) 3D printers (Fig 3.)-which replaced powder-based 3D printers in the workshops. The FDM printers were ideal for this task as producing models on the powder-based printers would have been time-consuming and cost prohibitive. The 3D printers can produce simple, cheap ABS or PLA models from CAD data. The inclusion of these small, affordable printers has greatly enhanced accessible prototyping activities within the department. Soluble support FDM printers are also being considered to improve model quality.

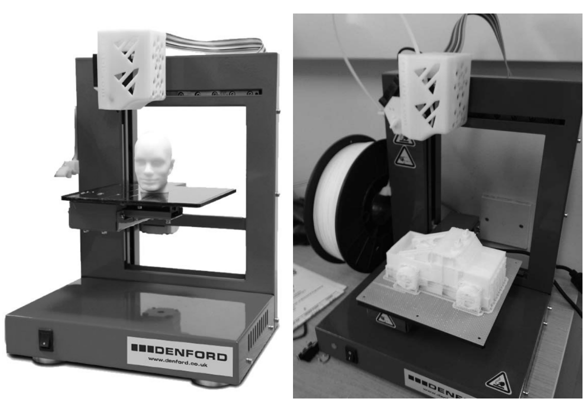


*Figure 3. PP3DP Desktop 3D Printer producing a car model*

With a 3D assembly of the toy car, which can be touched, rotated and taken apart, students were able to understand key construction features in parts, as well as how parts go together to form an assembly. It brought their CAD activities into context, where they were able to see a physical representation of their CAD model-generated from CAD data (Fig 4.).

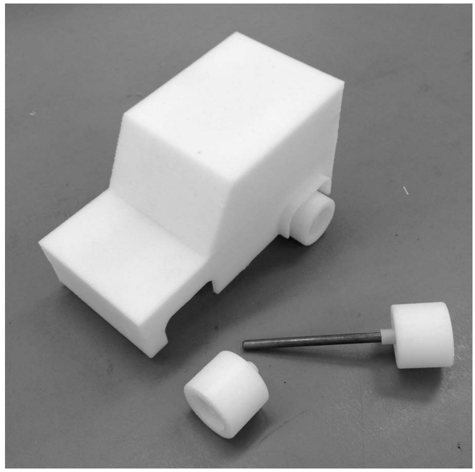

*Figure 4. 3D Printed model of basic toy car assembly*

## 4 IMPROVING CREATIVITY USING 3D-PRINTING

Producing a 2D orthographic drawing and exploded view of CAD assembly is the minimum submission requirements for the CAD assessment. It is expected that students spend time customizing their toy car in CAD by adding features like lights, radiator grills and wing mirrors to the model. One can see that the geometry of the toy car is basic-it represents a blank canvas that students can be creative with. The key incentive of this customisation process is that students attain extra marks for additional features. This has been enhanced by introducing 3D printed models of 'best of class' toy cars to inspire the next year (Fig 6.). As with the teaching aids, these 3D printed models also assist with spatial awareness and feature construction.

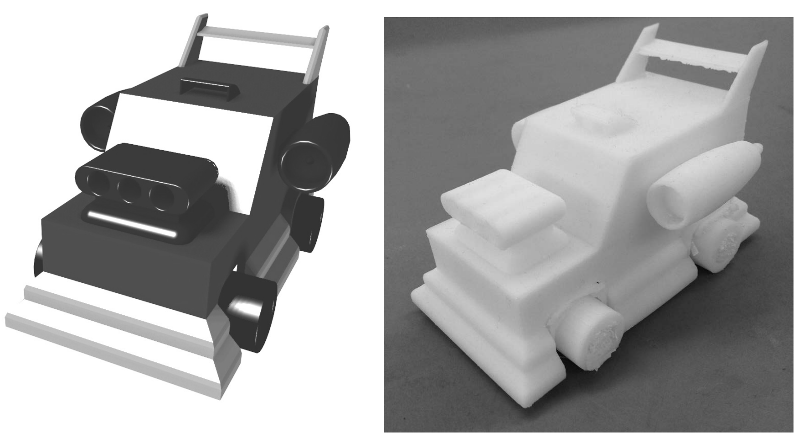

*Figure 5. 3D CAD model and 3D print of a customised toy 'rocket car' with additional features*

After each class, the best car is chosen by the teachers and the winning student is contacted to transfer the CAD files. The students tend to be keen in seeing the 3D printing process in action and their finished model-which is beneficial as they will become accustomed to prototyping in the next semester. Also, similar reward based methods for enhancing CAD teaching has produced promising results in secondary education D&T classes [5].

Thus, the incentive to be creative has been enhanced as students are:

- able to have their creative output physically printed as exemplars
- keen to out-do their predecessors and produce a winning car
- able to keep their models once the following year has run its course

Equally, the more features students add to the CAD model, the more marks are attained. This incentive is key in bringing the class average distribution of marks up. It also helps engage students who would otherwise pass with an average grade. Some additional learning outcomes of the enhanced CAD teaching could now include:

- Enhanced 3D spatial awareness, visualization skills and creativity
- Introduction to 3D printing to build physical models from CAD

## 5 INDICATIONS OF ENHANCEMENT

The following table shows the changes in average mark percentage for the CAD coursework submission, along with standard deviation, over four academic years (Table 1.).

*Table 1. Average mark difference and SD*

| Academic Year | Difference in average mark from previous year(%) | Standard Deviation (%) |
|---|---|---|
| 2010 to 2011 | +1.99 | 14.91 |
| 2011 to 2012 | +2.83 | 12.22 |
| 2012 to 2013 | +3.08 | 11.12 |
| 2013 to 2014 | +1.12 | 11.84 |

The following graph represents an infographic of average mark improvement, annotated with changes to the CAD teaching element over time (Fig 6.).

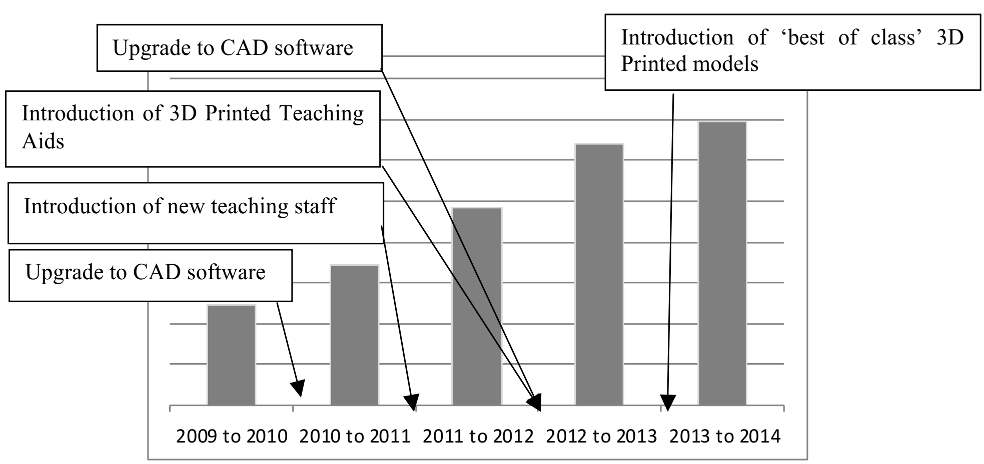


*Figure. 6 Graph of average mark improvement*

From observation, one can see a steady increase in average marks, regardless of inclusion of 3D printed teaching aids. However, note that the year of inclusion shows the largest increase in marks.
Other factors to note are the bi-annual upgrades to CAD software, which generally improve user interface and tutorial-based learning. Also, new teaching staff were introduced in 2011. The inclusion of 'best of class' models may have led to a slight improvement in results, however, the competency of students (now that CAD is accessible at secondary education level) also tends to increase. There are also external factors-such as computer gaming [1] when considering enhanced spatial 3D awareness.

## 7 FURTHER WORK & DISCUSSION

It is difficult to fully ascertain improved creativity and spatial awareness from summative marks alone. An alternative method could use spatial awareness exercises such as the Purdue Spatial Visualisation Test [7]. However it is difficult to isolate CAD teaching as students are currently enhancing their spatial awareness with drawing and model-making activities. Perhaps this is a cause of the problem-CAD teaching should not be isolated from 2D hand-drawings as well as 3D physical models and prototypes as they are interlinked, associated activities. For example, within a real physical space all views are naturally perspective-both 2D drawings and 3D CAD models can help explain and represent this phenomena-further enhancing spatial awareness.
The separation of CAD and hand-drawing in different teaching units could be due to legacy-and simply not appropriately updated for 21st century engineering practice. Plans to move CAD teaching into a design-led unit are being currently discussed. Hopefully this will improve the association of CAD with sketching, design processes and engineering drawing. The enhanced creativity element of CAD teaching would also help reinforce the change. In this respect, CAD could be taught in harmony within the design-orientated unit, with CAD visualisations supporting sketching activities.

## 8 CONCLUSION

It's hard to judge spatial awareness and understanding on summative information alone. A fundamental conclusion is the process and principles of teaching CAD and 3D sketching are interlinked-and support visual thinking and spatial awareness. To enhance further, artefacts can be used to improve spatial awareness, feature construction and assembly building. Accessible and affordable 3D printing technology can aid in the construction of 3D teaching aids-which could enhance 3D spatial awareness, understanding and promote creativity, however this requires further verification.

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# OBSERVATION: LISTEN WITH OUR EYES AND LOOK WITH OUR EARS

**Amos SCULLY**
Rochester Institute of Technology, USA

**ABSTRACT**
Design ethnography and design thinking stress the importance of thoughtful and considered observation. Observational engagement goes far beyond simply witnessing; active observation promotes awareness and curiosity through engaged 'seeing.' The observational viewer builds greater insight into empathy, place, social setting, both overtly and subtly. Establishing the power of observation can start with first year design students. This paper suggests that challenging design students in their first year undergraduate (Foundations) study to engage in site-based observational recording (written and visual) promotes insight, awareness, and self-empowerment for a creative response. This paper establishes the need for thoughtful 'seeing' that challenges preconceptions through multi-sensory experience that is employed in a Foundations student project with three case studies. Foundations students worked in a location of their choice, noticing formal characteristics, daily phenomena, and personal fascinations, and creatively responding to these. Asking a student to work in an everyday setting outside a classroom promotes site ownership and independent empowerment. While the student observation and response project exampled was not problem based, it initiates core principles of design methodologies.

*Keywords: Observation, Site, Foundations, Research*

## 1 INTRODUCTION

This paper poses the question "How can the Foundation year observational studies set the stage for design ethnography?" The act of observation plays a critical role across numerous fields, such as the sciences, engineering, humanities, but significantly in the creative arts. To observe is to 'pay attention to' or 'notice' (Oxford English Dictionary) as a personal first-hand immersive experience providing for discovery and inspiration with potential for meaningful advancements, reconsiderations, and creative output. Within the arts, observation can motivate personal expression or provide for user-based problem solving in the design disciplines. When practiced as a multi-sensory experience, key insights and inspiration can arise from the characteristics of observed movement, time of day, or emotional states expressed by the user. Developing a keen observational awareness or 'seeing' plays a fundamental role not only as a research tool for making designs insightful, but also to drive creative play. The field of Industrial Design stresses the importance of observational fieldwork known as 'Design Ethnography' as playing a vital aspect in generating an understanding of user-based habits and needs. While observational drawing is a staple of Foundations curriculum, drawing in an everyday setting primarily records formal characteristics and is often unable to include considerations of movement, mood, sounds, or dynamic changes. The need to 'listen with our eyes and look with our ears' is a challenge to look beyond preconceptions and to employ a greater depth of observation beyond formal characteristics.

## 2 COURSE AND PROJECT

The author's project titled 'Observation and Installation' was delivered in 3D Design in 2013. The 3D Design course is part of a Foundation Studio class set in the first year of undergraduate program, typically accompanied by 2D Design, and Drawing. The German Bauhaus School of the 1920s originally proposed the Foundations program in the burgeoning design field by employing simple observational objectivity as part of its materials-based visual studies [1]. The author's 3D Design course is a required class comprised of approximately twenty students per section from majors primarily in design, but also in the fine art and craft fields. Each student must create a journal consisting of a series of 'seeing'-based observations over a few weeks, and then create a response installation in the space observed. The project asks students to select an everyday location, a 'site' to spend time with recording observations, both written and visual, in a traditional bound journal. Journal entries occur at different times of days using descriptive words noting overt formal conditions, subtleties, and changes much like observational fieldwork. Stress is placed on drawing visual parallels and noting repetitions over time. The visuals may be as simple as comparing rectilinear forms in the foreground and background, or the repeated paths of people walking that may compare to the lines of trees. Students are also encouraged to discover personal fascinations. Installations are completed on site and photographed with images presented in the classroom.

The project takes advantage of everyday technology of cellular phone cameras for photographing final images and concept proposals. Conversely, the project dispenses with technology for recording still images, video or sound recordings as these are not conductive to immersion. Immersion through traditional journaling forces students to think critically and expressively by putting words to sounds, engaging in observational drawing, and considering how to record time, mood, and movement. The availability of digital technology to record on-site is often a barrier for being present, since one concentrates on the technology and not being present 'seeing' the site.

## 3 SEEING

The act of "seeing' is a heightened sense of engagement beyond that of just looking. Seeing suggests a viewer's appreciation of everyday events, environments, or objects, finding poetry in material others would find banal, ubiquitous or unimpressive. This heightened appreciation is an awareness that comes from an openness of mind, an interest beyond preconceptions. As George Nelson, the former Director of Design at Herman Miller, states: "We see what we have been trained to see by habit or tradition. The notion that we come upon a scene and see everything has no truth to it" [2].

The "habit or traditions" that Nelson refers to are in effect cognitive blinders, personal and/or societal, of the viewer's awareness. While his example refers primarily to visual awareness, Nelson's call to appreciation extends to Henri Lefebvre's writings on the social existence of space, suggesting that images receive a higher preference over other senses; in turn we become repressively visualized. Lefebvre states, "In the course of the process whereby the visual gains the upper hand over the other senses, all impressions derived from taste, smell, touch and even hearing first lose clarity, then fade away altogether" [3].

Without preference to the visual; the visual and the auditory can comingle, affording as the title suggests 'Looking with our eyes and seeing with our ears.' This state draws in a more experiential awareness, not just 'viewing' but allowing senses to combine to generate impressions that change throughout the day(s), affecting mood, or even resulting in dynamic changes. Sound can be beguiling, provoking interest in who or what made the sound, even evoking fear and wonder [3].

## 4 OBSERVATIONAL DRAWING

Direct observation or 'drawing from life' is an essential goal of a typical Foundations Drawing course. Observational drawing attunes students to capturing shadows, objects from different angles, light falling on glass, etc. These skills afford the student the ability to begin to visualize in the mind [4]. Direct observation primarily deals with capturing realism through recognition of values, perspective, and textures, and through techniques such as gesture lines, stippling, or blotting. A student spending time looking at an object or an environment and then drawing it experiences an appreciation of the proportions, shapes, depth, and details that visually communicate to the viewer. Recording through drawing can transform individual perceptions into a communication tool of social understanding. [2] Communication skills are not just elemental but also essential, and when put to work can create stunning and thoughtful recordings of the physical world. Essential design drawing textbooks such as Francis Ching's *Design Drawing* suggests that observation is recording the present, expanding memories of the past, while stimulating imagination for the future [5]. This expressive act of recording is an act of interpretation. What a student chooses to draw, how they choose to draw it, and how we as the audience interpret it are vital considerations for drawing as an expressive form. Yet recording through drawing can be limited during the Foundations program, and while expressive compositionally, it often just cannot account for a more robust sensory phenomena that true 'seeing' does.

## 5 JOURNALING

The author's student project begins with selecting a site. Students are asked to find an everyday location that they will observe and spend time recording in a journal. Students select a site that is distinct from their daily routine, one that they will visit over a period of weeks at differing times of day. The location is a personal choice, anything from a stairway, foyer, courtyard, or location in the woods. The journals are recorded on traditional paper or sketch pad, offering a place to freewrite and sketch observations. The goal is for students to engage a mundane setting to find them in a state of immersion, to make discoveries in a setting that seemingly offers nothing. Immersion is a state of mental focus that attempts to lose the real world in a feeling of satisfaction and joy [6]. As the paper title, "Listen with our eyes and look with our ears," suggests, good journaling accounts for mingling of senses not strictly visual. Using observations, students write and sketch, sensitizing themselves to what they see and hear, noting formal qualities, movements, changes, details and moods of each site. The journals have no prescribed format and students are encouraged to write in sentences or as single word lists, or to spend time sketching with details or just light-heartedly. The goal is 'seeing,' so the more personal and experimental the journal, the more the potential for immersion rises. A single entry may take fifteen minutes or an hour depending on the student's schedule or level of interest at a given moment. Like the work of an ethnographer, journaling is to be performed with an open mind, allowing for both expected and unexpected observations. Journaling may include observations of people in a space, documentation of what has happened, or noting the impact of weather. Like ethnography, journaling is not intended to engage or intervene but to find awareness and to engender curiosity.

As students begin journaling they often feel intimidated at the public nature of their chosen site.

Sitting with a journal in a stairwell or the entrance to a library can make for awkward social encounters. This feeling of inappropriateness is an obstacle to immersion that also affects the duration and content of initial observations. The nature of 'seeing' is such that one becomes aware that they too can also be seen. This reciprocal nature of vision where one is seeing and being seen is more fundamental than verbal dialogue [7]. However, situating one in a public setting and taking ownership offers tremendous empowerment. For the student there is great mental safety in the context of a classroom, the halls of a college department, or the personal desk of their living quarters. The ownership of a public site takes place as students mentally shift from awkward uncertainty in initial journaling to resolved immersion after subsequent visits. If questioned by acquaintances during their later journaling stays, students report pleasure being able to share their purpose and insights.

The student project flips from hands-off observer journaling to hands-on art making of an installation at the site to conclude the project. These large-scale temporary installations require a bold sense of ownership of the site. Installations may take hours to complete and not uncommonly students recruit friends to assist in the work. Ownership is at its height during site installation when students are questioned by curious strangers. There is often a reported sense of pride in explaining their purpose and concept.

## 6 SITE

The student project described utilizes real-world and real-time experiences through site journaling. Site-based work, more familiar in fields such as architecture or sculpture, derives from the conditions of a specific locale. The work produced is referred to as 'conditional,' meaning it is influenced by the circumstances of the site. Site-based work looks to the dynamics of a place and acts in response to what is actively observed there, a process referred to as "determining relations" or the conditions of circumstance [8]. Similarly, site-based work proposes an 'art-response' to judgments arrived at intimate hands-on reading through sitting, watching and walking through the site.

## 7 DESIGN ETHNOGRAPHY

Research in Industrial Design known as design ethnography came into prominence in the 1990s. The ethnographic approach of observational fieldwork, appreciating the 'real world in real time' was initiated to address computers in the workplace. Looking at the context of products and users at work generates a depth of understanding by the designer who had not previously considered social relationships. This first-hand experience fieldwork sheds light on social scenarios and environmental influences surrounding product use, supplying the designer with information to inform an analytic perspective. Observing a person using a product generates insights into the struggles and opportunities of a design or scenario with which the designer is tasked. Often the problems or opportunities are unable to be identified by the user but can be observed by the designer, who as an ordinary member of society acts as a sociologist. Recording this is a matter of "getting down on the shop floor, immersing yourself in the work, and learn through first hand experience" [9]. Assembling the record can be achieved through a variety of means such as field notes, diagrams, photographs, and video.  Insight of this manner optimally engages the designer by sensitizing them as ethnographers to ubiquitous features. These 'user observations' are best performed by observing without intervening in the user workplace, instilling the designer with both expected and unexpected situations and use realities. The unexpected is only discovered if the designer enters with an open mind and is keen on subtleties (van Boeijen et al). Ethnographers can place a prototype into the workplace setting to consider its effectiveness. The insight of user observations should take into consideration users knowing that they are being observed and therefore that they may behave differently than they would normally.

## 8 CASE STUDIES

The studies below are representations of the project titled "Observation & Installation" from the author's first-year Foundations 3D Design class. The project was delivered in two sections with thirty-eight participants in the ninth week of the first semester.

### 8.1 Tanya

Tanya observed a public bench in a quad a few minutes walk from her dormitory. Her observations include notations of leaves on the ground changing colours, how the breeze is so soundless "it's almost as if the breeze would be interrupting if it made a sound any louder," and her excitement of a leaf stuck in the gap between slats of a bench that she took a particular interest in. She recorded sounds of laughter in the distance, "soft rain," and "feet moving on the pavement," and spent time drawing shadows.

In writing about her visual and auditory experiences she used words employing alternative senses. Visual observations in an environment can leap to auditory descriptive words such as 'noisy,' while other words with visuals would be described as 'brown' sounds or 'fuzzy' smells. These overlaps suggest a poetic appreciation for seeing a place or object. Revisiting a setting over time can allow one to see dynamic changes in movements, sounds, and moods. These changes lend a greater depth of understanding through subtle or dramatic differences.

Tanya noted the number of cigarettes on the ground at each visit' she timed and speculated on the duration of smokers sitting according to the temperature changes. These observations and interests are in keeping with design ethnography. She also noted the "beautiful story" told by the wear on the bench planks. Her creative response was to construct a human-scale cigarette placed on the bench inspired by noting the similarity between the folds of the crushed filter to the folds of a seated woman's skirt. (see Figure 1)


*Figure 1. Installation : Tanya*

### 8.2 Jocelyn

Jocelyn observed a women's dormitory bathroom. Her observations included the frequency of the cleaning staff visits, the scents left from beauty products, bleach, and the affects of moisture. She

charted diagrams of colours and counted their use. She became interested in shower use: "I think it would be interesting to see how people's shower habits change when they have less time."
Jocelyn's proposition is akin to a design ethnographer's placement of a prototype into the workplace setting to consider how it affects work habits. When ethnographers observe prototypes inserted in the workplace must take into consideration users knowing they are being observed and possibly behaving differently than they would normally. This method is best complemented by acknowledging the user as expert. Users are often unable to identify the issues, problems, or limitations with the products that they use frequently. Use of 'context mapping' asks the user to do homework activities that empowers them to provide insight on their experiences through subsequent group session interviews [10].
Jocelyn did not attempt to alter the showering habits, but her speculation is in keeping with inserting a prototype. She noted many conditions such as the difficulty to determine time of day without windows, and keenly noticed the frequently colours of the bars of soap were being used (and left behind), matching the palette of the floor tiles. Her response installation was to make a set of tiles the same schedule and size on the floor out of corresponding bar soaps. The tiles she made were then attached in a band to the shower, appearing like a true set of tiles.

### 8.3 Damian

Damian observed a public tunnel below an academic building. He sat where an intersection of two tunnels merged. Damian noted the colours, the affect of light on the colours, and the absence of anything that was organic. He observed that every surface had the presence of texture: "the ground…is made out of brick that is also made out of tiny specks of light that reflects less of the white side than the orange side." He watched how people moved and reacted at the corner intersection. He became fascinated with the form of a corner as a condition of the wall being three dimensional, stating "Every corner has a force." He began to write in the manner of a manifesto about corners: "a circle is opposite of a corner since it is made of zero corners or possibly a million corners." For his installation Damian made a set of circles constructed in paper that lay as a pattern on the floor radiating from the corner of the wall.
Research ethnography considers the 'site' of a workplace as a unique conditional factor to the success of a product. In the case of Damian's project, site-specific work is conceived with the site as an integral element to its success. Site-specific work is integrated into the surroundings through a process of recognition and understanding. Damian was able to recognize the banal corner as a "force." Ethnography must examine banal everyday conditions and find inspiration in these.

## 9 CONCLUSION

The project "Observation and Installation" enabled students to immerse themselves in an everyday public site outside of the classroom, immersing them and taking ownership. Although this project is not directly geared at 'user observations' as with design research, both share the realities of the expected and unexpected of direct site observation. Both require insertion into uncontrolled environments and taking ownership in order to find opportunities and spark creative responses. Ethnographers, like these students, practice immersion on-site, and through their observations of mundane settings and the practice of 'getting down on the shop floor' look for reoccurrences and seek inspiration.
Concept generation across the two class sections was generally strong, suggesting that on-site response was successful. Embracing the observed conditions as 'seeing' transcends preconceived concepts.
In the project critique students expressed great empowerment by taking ownership of a site that occurred in their repeated visits, exhibiting pride in their journals and even recruiting friends to assist in their installations. While the journals gave students pride, they often stated 'everything is the same.' This statement, while discouraging, validates that students need to build observational sensitivity and therefore pedagogical practice should emphasize the use of observation at early stages. This paper's title suggests that the undertaking not be biased toward the visual, yet the final project deliverables in printed images from cell phones makes the visual take precedence. Considerations of how to incorporate sound, mood, and movement should be incorporated, since the project does not allow experiencing the installation first-hand.
Shared outcomes of the student observations to design ethnography:

- Learning to value open-minded expectations
- Sensitization to the mundane and ubiquitous

- Use of observational recording
- Observing the actions/habits of people in an environment
- Empowerment of observer outside of routine environments
- Finding opportunities for creative response into workplace/site

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## Chapter 14

# CURRICULA

# METAPHORS IN DESIGN CURRICULA

**Viktor HIORT AF ORNÄS[1], Martina KEITSCH[2] and Kjersti SCHULTE[2,3]**
[1]Department of Product & Production Development, Chalmers University of Technology
[2]Department of Product Design, Norwegian University of Science and Technology
[3]SINTEF Raufoss Manufacturing

**ABSTRACT**
Metaphors are central to the way we see and shape the world, and identifying metaphors can help to question how certain issues are explained or set-up, thereby opening up a range of opportunities for design. This paper explores how metaphors can contribute to understanding theories and models, as well as problems and opportunities in design courses at different levels. Following the introduction, section two and three introduce metaphors, and identify the roles metaphors play in design and design education with help of analyzing three examples in design curriculum. The fourth and final section discusses educational implications of metaphors as tools to inspire and facilitate knowledge generation in design curricula.

## 1 INTRODUCTION

Design is art. Design is problem solving. Design is a journey. Design is a bricolage. Design is creating specifications for that which does not yet exist. Design can be seen from many perspectives, and is often described by using a metaphor [1, 2, 3].

"Metaphor has the extraordinary power of redescribing reality" [4]. Metaphors shifts attention to certain features; changes the salience of certain aspects. In design metaphors matter for how problems are framed, for the ability and legitimacy of different stakeholders to influence a project, as a way of generating ideas, as well as for overall themes for a project, driving decisions. A designer, who sees design as a process of selection is more likely to list options and then select between them, whereas a designer who views design as a dialogue is more likely to generate and test a number of options with stakeholders, iterating towards a solution. Engaging with metaphors can help students frame and reframe problems; "Instead of re-using known design schemas and familiar solutions, the implementation of metaphors in practice can contribute to unconventional thinking and thereby generate more innovative design products" [5].

In prior papers, we have discussed the importance and challenges of engaging design students in reflections on underlying perspectives and assumptions of different starting points, and that the understanding of design theory can be facilitated by contextualizing it within more applied activities in design education [6]. Furthermore, teaching and learning activities at different curricular levels should take different forms. Students at higher levels are expected to display and should also be given reflexive independence to autonomously seek new knowledge expansion and insights. However, novice students should be gradually introduced to tools and techniques enabling them to cope with complexity, exposing students to challenges that are just within reach [7].

In curricula, metaphors provide ways of understanding theory and can also support training the students' critical reflexivity and professional skills. This paper explores how metaphors in an educational context can both be used in a practical perspective and contribute to understanding concepts, models and applications in design courses at different levels.

## 2 METAPHORS AND DESIGN

Metaphors bring out the thisness of a that, or the thatness of a this [8, p.503]. The term metaphor stems from Greek metaphora – 'a transfer'. A metaphor is per definition a comparison between two or more seemingly unrelated subjects, where the first is described as seemingly equal to the second in some way.

Metaphors emerge through an imagination, which connects denotative and a connotative meaning. In 1979, Nelson Goodman emphasized the significance of metaphors for the process of structuration and interpretation of the human world. In Goodman's opinion metaphors are important elements in the process of knowledge generation: "…in replacing some 'stale' natural kinds with novel and illuminating categories, in contriving facts, in revising theory and in bringing us new worlds" [9, p.125]. In addition to definitional and descriptive explanations, metaphors provide specific means for understanding and indoctrination, which can be more powerful than direct arguments. Metaphors affect the way we perceive the world, categorize experiences, and organize our thoughts [10]. They convey ideas but also distort and simultaneously reveal and conceal [3], highlighting different areas of concern, entailing different priorities.

Metaphors provide ways of understanding theory. Besides training a critical reflexivity towards texts, metaphor analysis can enhance the learners' capability to grasp the theoretical foundations of a subject instead of learning én route. Metaphors have a heuristic character, they can help to negotiate meaning and find a consensus. Metaphors often appear as linguistic affair however, Lakoff and Johnson [10,11] suggest that metaphors are not only a matter of language but depend on bodily experiences as well. This is supported Parsons [12] who proposes that metaphor is a kind of connection between body and mind. In education, this opens up for new and creative ways of understanding with the help of metaphors.

The strength of metaphors is the way that they form images and understanding. On the other hand, it is crucial to understand that metaphors are simplifications, where certain characteristics are emphasized and others are ignored [13]. For example, economic metaphors have large influence on our society, also in non-business areas such as politics, and academia [14]. Notions such as 'market' and 'competition' are so widely used in design as well, that we might not recognize them as metaphors from an economic theory anymore. Lakoff and Johnson argue, that "we often take the metaphors of our own culture as truths" [10, p.186]. The idea of competitive markets as a 'natural law' originated in 1786 in Jospeh Townsend's dissertation about the struggle for existence between goats and dogs on the island of Juan Fernandez [15]. Successful metaphors in economic theory refer to phenomena in real-life and are reinforced by becoming part of the natural language [14].

Design has particular strong relationships to metaphors. Metaphors tacitly affect how design is viewed and discussed as e.g. Schön points out in his famous article "Generative Metaphor": "Once we are able to see a slum as a blighted area, we know that blight must be removed ('unsanitary and unsightly') buildings must be torn down (…) The metaphor is one of disease and cure" [16, p.147]. Metaphors can also deliberately support design thinking [5], noticeable in designs such as the desktop metaphor for computers, in drawing on parallels to nature (see e.g. Benyus work on Biomimicry [17]), in methods for generating ideas [e.g. 18], embodying brand values [19], or communicating about products [20]. Metaphors are used to convey ideas. In working with students' information search Gröppel-Wegener and Walton [21] compares the search for academic sources to fishing a sea of information that can be surfed or trawled yielding large number of catches or fished more selectively. Some sources are shallower, others deeper and more theoretical, some catches have more teeth and possibly require more struggle. Like diving, the practice of dealing with different sources takes practice.

Metaphors are also central to design practice; "…even when playing with geometry, the process is never entirely geometrical. Shapes are never merely just shapes but also sunbursts, leaves, rays, clouds, tokens, wings, crystals, windowpanes, walls, symbols, reminders of shapes previously encountered, previous design experiences, and precedents. Each metaphor brings with it new entailment and new actions" [22, p.115]. Metaphors are crucial for communication in design processes surrounding products, which often requires balancing different perspectives (e.g. manufacturability, price, expression, usefulness for the end user etc.). Design is here seen as a collaborative activity in which different actors have a more or less strong say. Describing the target group as users may here imply an emphasis on products as tools to be applied for some purpose whereas describing the same group as customers may imply an emphasis on products as goods and economic transactions. Metaphors play a central role in the discussions and discourses between different actors. How a project is framed also affect the legitimacy with which different stakeholders can affect outcomes.

## 3 ROLES OF METAPHORS IN DESIGN EDUCATION

Metaphors are important to design theory, practice and education. However, students naturally face difficulties in understanding the role metaphors play for design.

### 3.1 Example1: Metaphors in Ideation

Our first example concerns a master course in form design given at Chalmers University of Technology 2013. The students are from a technical program and trained in addressing aspects of use (relevance, usability etc.) as well as mechanical design. However, in this course, students should to engage in a design tasks from the other end; i.e. letting aesthetics and symbolism drive the project.
As part of this course we held a workshop in which the ambition was to engage students in reflection on how metaphors could drive a design proposal. Students were given a set of random metaphors focusing on artefacts, animals, characters (e.g. super heroes and famous actors) and activities.
These were selected to comprise metaphors that had physical characteristics, behaviours, and abstract activities The students were asked to move in a stepwise process: First analyzing the metaphor in terms of physical properties and structure, behaviours and function, and assessing its significance in terms of values represented by the metaphor (b) Try to apply the metaphor to a new solution (a lunch box) in a projective exercise.


*Figure 1. Some of the metaphors given to students (Cards courtesy of Maral Babapour)*

While the students did develop novel ideas, they seemed to have problems choosing a metaphor to explore in depth. It seems they easily got entangled in transferring surface level attributes, but that they had problems transferring more implicit content such as symbolism, behaviour and relations between elements to their design problem.

### 3.2 Example 2: In-situ Metaphors

Our second example concerns a master course in "Design strategy" at The Norwegian University of Science and Technology in 2014. The learning goal of the course is to understand the complexity of a business. The students develop a future vision for a case company, and then frame specific strategies consistent with the vision. One strategy concerns business relationships. Throughout the design study the students have learned to analyze competitors and to differentiate products in the market place. These tools are in line with the competitive market view in economy, which is commonly illustrated by the metaphor the 'jungle' [15]. On the other hand, a relational strategy may also focus on cooperation between companies, mutual dependencies and interaction among actors a view that can be illustrated by the metaphor 'rainforest' (Ibid.).
The ten students were first asked to contemplate on how they view the business world, and their first association was competition. Then the students were asked what they associate with the words 'Jungle' and 'Rainforest'. Associations to 'jungle' were dangerous, wild, and the survival of the fittest. In contrast, the 'rainforest' is harmonic, diverse, and fruitful. Throughout the rest of the discussions, we alternated between focusing on the competitive situation for the case company and its interaction

with suppliers and customers. The class clearly understood these metaphors. The metaphors were also introduced in a similar course in 2013. But then the majority of students could not differentiate between the two metaphors. One reason might be that in 2013 the course was taught in English, whereas in 2014 the entire class was speaking Norwegian. When the students did not see a difference between the two words, the metaphors did not function as different lenses to use on the case.

### 3.3 Example 3: Metaphors in PhD education

Our third example concerns the PhD course "Topics in Design research" at The Norwegian University of Science and Technology, which aims to provide insights in prominent design theory paradigms. The course covers a theory of science introduction for designers, as well as a discussion and analysis of design theories. One assignment in the course was to detect and analyze the use of metaphors by the authors of three theories to evaluate if they were consistent with their theories. The five candidates were firstly introduced to metaphors and followed by one-month homework to examine metaphors in the texts. The candidates detected metaphors and were able to discuss if these contribute to clarify or blur the author's message. However, they did not have a lot of background knowledge about the authors, the history and the context of the theories, and only found the most obvious metaphors. A positive aspect was their genuine interest in how metaphor analysis can be done and their surprise of how greatly the metaphors influenced the meaning of the text. Students on this level understand that these texts have relevance for their research work and therefore theories are interesting. A future approach should give a more design-specific introduction on metaphors.

*Table 1. Roles, Benefits & Challenges for the specific examples*

| | Example 1: Ideation | Example 2: Realization | Example 3: Recognition |
|---|---|---|---|
| Role | Analyzing and projecting metaphors on a design solution | Analyzing the business world for a case company | Analyzing metaphors benefit for clarifying design theories |
| Function/ benefits | Training students in actively elaborating problem- and solution space | Explaining concepts from another domain (economy). Making students aware that theories influence how we view the world | Making students aware of the implicit power of metaphors, ideally training them to consciously use metaphors in their writings |
| Challenges | Students had problems moving beyond literal analogies | Understanding differences between alternative metaphors | Poor background on design theories and their epistemological fundaments |

Comparing the examples from courses above, we see different roles for metaphors in design education, serving different functions and implying different types of challenges. Regardless of whether students engage with surface level attributes, or underlying relations and implications, working with metaphors require practice, skill and prior knowledge.

## 4 EDUCATIONAL IMPLICATIONS

Metaphors inspire and facilitate theory and practice knowledge generation in design curricula. As the former sections illustrate, metaphors can play different roles in education, implying different levels of engagement, requiring different levels of skill and effort, but also have differences in potential impact. We see the following as main opportunities for the use of metaphors in design curricula:

- On a basic level, metaphors can inspire and enable playful comparisons of similarity in appearance or behaviour, which may support speculative reasoning e.g. *transferring* manifest and implicit attributes from one context to another for ideation purposes (What if the product was like…?). While exercises as that in example one above do not imply any deep engagement with a material, they may serve as entry points for working with metaphors.
- On a an epistemological level metaphors may serve as lenses supporting *seeing* a phenomena from a specific perspective ('seeing as')

- Using metaphors as keys to perspectives may also give students a more comprehensive understanding of a theme. Given that students get the conceptual tools and skills to engage with the metaphors that shape our understanding they may start questioning starting points and underlying values, *employing* the metaphor in reflections and explorations around a theme
- On meta-level metaphors may contribute to critical reading of a text or concept. *Comprehending* the metaphor as such, including assumptions and implications can also teach students how to use metaphors deliberately in their own texts. Training in analysis of metaphors could make students aware of ideological terms in design literature and might strengthen their analytical abilities and argumentation skills, drawing attention towards what is 'taken-for-granted'.

In the courses described in the prior section, students sometimes found it challenging to come to terms with specific meanings of certain metaphors. To use a concept as a metaphor students need to be familiar with it. Seeing how phenomenon is framed is potentially powerful, but seeing what a certain metaphor reveals and conceals presupposes knowledge on how the phenomenon could otherwise be portrayed. Making assumptions, axioms and values explicit may also require that different metaphors are compared and contrasted, see [16]. Before developing fluency and a repertoire, students may find the introduction of different metaphors confusing. Furthermore, students from engineering disciplines may have a difficult time coming to terms with the inherent vagueness of metaphors as they are typically schooled into putting premium on precision and grand truths rather than competing narratives. An additional challenge with metaphor exercises lies here in their indirect character – metaphor analyses do not provide immediate benefits and are time consuming. A task for the teacher is here to guide the students not just through the recognition and application of metaphors but also to show their limitations.

Metaphors are pedagogic tools for conveying certain ideas, providing ways of structuring thinking and understanding abstractions. Advanced students might also benefit from explicit discussion on metaphors as such to support reflections on their own practice. Text analyses can e.g. be included in design curricula with the goal to understand and build explanations, arguments and metaphors.

Metaphors can support learning in novel ways and contexts. For beginners, they can be used to encourage students to structure thinking and understand abstractions. In the medium phase of education, metaphors serve to making students aware of ideologies in design literature and this might strengthen their analytical abilities and argumentation skills. For advanced students - understanding metaphors trains their attention towards what is 'taken-for-granted' and contributes to revise petrified assumptions Engaging with applying but also scrutinizing metaphors can support students in practical design work, as well as reflections on their practice.

While it is not certain that it will help the students come to terms with what design is, actively employing and examining what different metaphors enable and entail may help expand perspectives on what design *can* be, in general as well as in a specific project.

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# INTEGRATING DIFFERENT USER INVOLVEMENT METHODS IN DESIGN CURRICULUM

**Martina Maria KEITSCH**
Department of Product Design, Norwegian University of Science and Technology

**ABSTRACT**
User involvement is increasingly gaining recognition and the number of user-researchers in the international design community is growing. However, the question: “Designing with users, how?” implies great challenges for scholars and educators, such as if user involvement necessarily results in user empowerment or just complies with an ideology of involvement, and if it leads to better products and services. The author discusses different concepts of user involvement and presents an education effort to teach user involvement methods in a Master Course in Sustainable Product Design. The methods are located within three domains - an abstract, a fictional and an in-situ user involvement concept. They have to be applied in the course during the last two years. The impact of the different methods on the students is discussed by analyzing some of their group works in the course. In summary, it seems that sustainable product and -service design curricula may advance by adopting a thorough user perspective. Generating knowledge on the benefits and pitfalls of the different concepts, and on how these influence methods and design practice is however crucial to integrate user involvement successfully in sustainable design curricula.

*Keywords: User involvement concepts and methods, personas, interviews, co-creation*

## 1 INTRODUCTION

The main hypothesis of this paper is that different concepts on ‘users’ produce different methodologies and practical approaches for user involvement. Therefore, it is important to teach students what kind of concept they work with and what kind of results they can expect. The objective of this paper is not to give a final account of all user concepts but to expose important relationships between the interpretations of users and design outcomes in a curricula context. I teach the selected concepts in a Master Course on Sustainable Design and have tested them within a period of two years. They represent exemplary approaches: Design as problem solving [4], design as reflective practice [8], design as semantic construction [11] and design through user innovation [14] with explicit views on the users’ role. Following this introduction, the second section of the paper discusses the concepts above, before coming to the course and an appraisal of students’ works in section three. Section four concludes with a discussion on benefits and disadvantages of the different user involvement approaches and their appliances in design curriculum.

## 2 KEY TERMS AND CONCEPTS

The term user implies quite different interpretations. The most common explanation means a person who interacts directly with a product or a service. Eason[1] placed users in three categories: (1) primary users, i.e. frequent hands-on users; (2) secondary users, using the product/service through a mediator; and (3) tertiary users, people who are affected by the product/service and might influence its purchase. Business theory classifies among others between lead users, people who are pioneers for products/services that might become trends later on [2], and end users, who finally employ the product/service. This paper applies the first explanation signifying the role of users in different design concepts. Involvement [3] means here (ontologically) to participate mentally or physically through engagement and action and (epistemologically) ways of thinking how this participation could take place. The focus of this paper is on how the concepts consider user involvement, what role it plays and (if) how it is practically done.
*Design as problem solving:* Herbert Simon's design concept consists of two aspects that influence his view on users significantly: rationalism and pragmatism. The rationalist/positivist view manifests in

the assumption that knowledge about nature is 'objective', unconstrained by the development of the natural sciences. For Simon, design can e.g. mediate a "…body of intellectually though, analytic, partly formalizable, partly empirical, teachable doctrine about the (design, M.K.) process" [4]. In the 'Science of the Artificial', Simon asserts further that design has to solve 'ill-structured problems' and that time and money is often lacking. Because of time-money constrains, design processes are always concerned with "resource allocation" [5]. Pragmatist/instrumentalist is the belief that something is true if it works satisfactorily and that unpractical ideas should be rejected. Simon's theory of design as problem solving is centrally concerned with how people handle complexity by reducing the (design) problem and selecting a solution from a set of alternatives. Simon claims that a large part of design problems can be solved by heuristics belonging to bounded decision-making [6]. Bounded decision-making means that choices are limited by lacking information, cognitive limitations and a finite amount of time to make decisions. Simon sees users as 'designers' and perceives a relationship between 'official' designers and users game-theoretically: designers make a move through design, and users make a countermove by utilizing the design, which in turn might trigger improvements. This game-theoretic concept on interaction between designers and users the second play a role after the designers made the first move. Simon's approach remains thus cognitive and instrumental, rather putting weight on the underlying logics of the game than on the social dynamics. One could refer here to abstract or symbolic user involvement [7], where input from users theoretically considered but does not take place in the concrete design process.

*Design as reflective practice:* Donald Schön's concept concurs with pragmatism and pedagogy i.e., the primary motivation for human activities is always a practical need and education is a necessity and a pillar for the continuity of our culture. Schön's crucial argument is that lifelong-learning is possible (and desirable). This represents a hermeneutic (self-reflexive) endeavour that connects existing professional experience with surprise, or even confusion within a situation, which is uncertain or unique [8]. This 'reflection-in-action' can (dialectically) contribute to a new understanding of the problem and change a situation. By becoming aware of former tacit frames, the practitioner sees now new links and relationships to the problem. Schön asserts that the cultivation of the capacity to reflect in action (while doing something) and on action (after having done it) as well as the ability to engage in a process of continuous learning is defining characteristics of professional practice. Schön's theory is language centred and so is his user involvement approach. Besides his arguments for explanatory communication (teacher-student, designer-client relationships) his claim, that that the framing of problems often depends on stories for problem setting and problem solving told by different actors is an interesting aspect for user involvement [9]. Schön argues here that a conflict depends on various views that to understand the users, views may change a problem description entirely. In this context, one can argue that the user should already be actively involved in early design phases (framing the problem).

*Design as semantic construction:* Klaus Krippendorff's concept grounds on social constructivism and a linguist paradigm, i.e. the possibility of genuine descriptions and interpretations of the world by language. Social constructivism assumes that individual knowledge and social knowledge are identical, culminating in the "social construction of meaning" [10]. As design theorist, Krippendorff puts a lot of emphasis on what artifacts mean to the people affected by them (design semantics). For him, design "brings forth what would not come naturally (...); proposes realizable artifacts to others (...) must support the lives of ideally large communities (...) and must make sense to most, ideally to all who have a stake on them" [11]. This human-centred approach opens, among others, for a discussion about relationships between professional designers and the network of users they cooperate with. Even if Krippendorff's concept invites for interpretations of fictional users it includes the possibility to initiate a collaborative process, which strengthens communication between designers and users.

*Design through user innovation:* Ernst von Hippel's two holy conceptual cows are democracy and innovation. The first relates to a liberal capitalist democracy: "Democratization of the opportunity to create is important beyond giving more users the ability to make exactly right products for themselves. As we saw in a previous chapter, the joy and the learning associated with creativity and membership in creative communities are also important, and these experiences too are made more widely available as innovation is democratized" [12]. The second concept 'innovation' means a new idea, practice, or object perceived as such by an individual, a group or an organization. The current economy relies on the idea to apply innovative knowledge and practices for production purposes, which emphasizes their commercial character and focuses on a progress that confirms certain principles about what is 'good' and 'useful' and what is not [13]. Von Hippel's democratized user innovation approach focuses on a design process in which the users themselves do part of the innovation within a set environment. The starting point is to employ skills and languages they already know and the users' role is to be design 'team members'. As professional designers, users are supposed to experience trial-and-error cycles when designing a product. The experienced consequences of the design choices facilitate, according to von Hippel, more precise design decisions, increase users' creativity and lead to better products. Thus his advice: "Managers in user firms … need to learn how their firms can best carry out development work in their low-cost innovation niches: how they can best deploy their information-related advantages of being actual users and residing in the context of use to cheaply learn by doing. Managers in manufacturing firms will want to learn how they can best play a profitable role in user-centred innovation patterns when these play a role in the markets they serve" [14].

### 2.1 A summary of the users' role in the concepts

A concept that assumes participation as mainly rational and discursive activity (Simon, Krippendorff) leads to seeing users rather detached from in-situ creative involvement in the design process. Users are either as perceived as abstract (approachable via statistics, behaviour studies, or stereotypes) or as fictional (approachable via personas-, scenario-, narratives methods). Concepts that focus on individual understanding, inclusion and expertise (Schön, von Hippel) imply on the other hand, in-situ engagement with users and their experiences. The challenge for the first concept group is to realize the life-worldly fundament of users as well as of designers experience and for the second to acknowledge that even the most individual experience may under certain circumstances give access to phenomena of a truly shared character. Keeping the concepts, in mind the following section examines methodological consequences of the concepts for design curriculum.

### 2.2 Methods derived from the concepts

Figure 1 illustrates different levels of user involvement as introduced to the students in the Master Course in Sustainable Design.

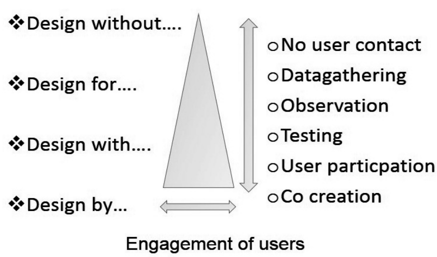



*Figure 1. Levels for involvement of users*

In principle, the students were free to use any kind of information and method from data/document analysis, via persona development to interviews or focus groups.

| *Information type and data colection* | *In-situ and fictional* | *Abstract and symbolic* |
|---|---|---|
| *Physical, environmental* | personal experience with relatives, interviews | survey of consumer behavior |
| *activities* | interviews articles, stories, movies, metaphors | Statistics on consumption |
| *intellectual* | literature, novels. movies | Reports governments NGOs |
| *social* | interviews, literature | survey of social situations, statistics |
| *ethical* | Interviews, codes of conduct | |
| *aesthetic* | Users in media, presentation of existing products | Formal aesthetics |
| *specific* | Individual tests, interaction with products and services | Environmental and technical reports, LCA<br>Existing product development |

*Figure 2. Information and data gathering*

When introducing the methods, we also touched their conceptual backgrounds, but the focus was to apply them for the course assignment. Before coming to the overview of the course and the appraisal of the students groups' works in section three, I will shortly present them. *Data/document analysis:* The main approach here was Life Cycle Assessment (LCA), which is familiar to the industrial ecology students. LCA estimates energy and material impact data of products from resource extraction to recycling and attempts to improve the product performance. *Persona Development:* Personas are fictional characters that represent the needs and goals of users in a nutshell. A persona is a user for whom the product/service is designed. Personas usually comprise the following information: A *personal profile* including age, gender, education, hobbies, family, socio-economic group, special characteristics and so on. A *role, which* relates to a function or professional position, for example for work-centred or home-centred solutions. A *background-story* consisting of a narrative past and a set of facts for example what house the persona lives in, where parents/kids live, where they went on their vacations, etc. [15]. *Interviews and Focus Groups:* The student groups chose semi-structured interviews with an open framework and used the results to identify interest areas for the concept development. Two student groups used focus groups to test their solutions and collaborate further with the users.

## 3 THE COURSE AND THE IMPACT OF DIFFERENT USER INVOLVEMENT METHODS

Sustainable design (TPD4145/5100) is a course given at the Norwegian University of Science and Technology. During the academic years, 2013 and 2014 we employed user involvement methods in teaching and learning activities and made it part of the students' assignment. The course is for 3rd year students from both design and engineering with a large proportion of international (exchange) students- it exists since 2007. It consists of 30-45 participants, who are divided into 4-6 groups with a main assignment that they chose themselves from the overall topic: Sustainable household practices. Historically, the course has introduced students to industrial ecology, design for the environment, life cycle assessment and other technical starting points to reduce detrimental environmental effects by e.g. reducing energy consumption or waste management etc. However, an ambition had been to expand the focus of the course from technical starting points towards sustainable practices, the inclusion of different user perspectives in eco-design, and the consideration of alternative framings for the problems be addressed. Behind the 2012 revision of the course was an ambition to make students capable of addressing a wider range of issues, and deliberately engaging with problems differently by taking on users' perspectives for problems and solutions in 2013, and addressing these through designing either a product (A), a service (B) or an information system (C). Looking at the results, the most popular method was fictional user involvement, namely persona development backed up by surveys and, in one case, semi-structured interviews. Two student groups had chosen to analyze and improve the material and energy impact of the product. One group worked with in-situ user involvement in form of focus groups - their concept highlights the communicative experience of the user. The three following examples illustrate in which way the single projects applied user involvement methods.

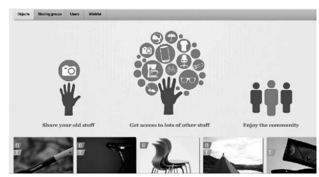
***The charger:*** The students group dived quickly into the details of the main product. The material focus brings recycle solutions for diminishing the amount of energy, however without taking into consideration other polluting parts of the products life cycle or change of charging habits. The product improvement was good but incremental.


***The grocery solution***

This was a project in cooperation with a supermarket. The solution was user oriented methods were interviews and surveys. The solution was little pleasing aesthetically and could have benefitted from in-situ user feedback.


***Loop***

Webpage for lend, borrow or swap items within a limited geographic area (students houses in Trondheim). Great deal of direct user involvement by interview focus groups and testing, this is the students' own user group.




## 4 FINDINGS AND OUTLOOK

What kind of knowledge is important for designing for and with users? From the author's point of view, methods for user involvement cannot be unified but one should be able to select from a fundus of different approaches according to theory- and practice-tasks at-hand. For example, the greatest benefit of abstract user involvement is that one can determine parameters and validate concepts with help of deductions from theories or by using quantitative, empirical data. One pitfall is that these methods do not allow interpreting human behaviour and activities in-depth, especially not by students whose theory background is rather limited. This disadvantage makes concepts/solutions based on abstract user involvement suitable for incremental changes but, from author's perspective, abstract user involvement does not contribute to create innovative concepts for sustainable design.

According to Long [16], who tested student groups working with and without personas in product development, personas strengthen their focus on the end user, their tasks, goals and motivation. Persona development introduces new ways of thinking to the students that prepares them to consider stakeholders to a higher degree. It also contributes to ensure that everyone in the group is aiming at the same user. One of the most challenging tasks for the student groups in the course was however to make personas that did not resemble themselves. Further some personas designed by the students were so flat that were dropped altogether - persona drawing requires experience and practice. Using personas in sustainable design curriculum are nevertheless a 'golden midway' between abstract involvement and real user involvement. Personas drawing could be supported by other creative techniques as well such as scenarios, and back-forecasting techniques.

Involving real users in workshops etc. is time-consuming but has the best effect in teaching the students not only facts and methods but also in fostering their active role in the learning process. Despite this value, involving real users is a challenge, especially in end-phases of projects e.g. in terms of how to evaluate and 'translate' users' suggestions into design concepts. A practice oriented co-design approach [17], which involves users already in the situation/problem definition phase and keep them immersed through the whole design process, could contribute to make conversation *and* goal definitions easier.

In summary, user involvement is in any form important for design curricula for at least two reasons. First, when designers meet future sustainable design challenges a systemic approach is required that integrates different disciplines and stakeholders [18] second, because future practitioners should be able to communicate with their surroundings - not only instrumentally about what is possible to achieve and how, but also ethically about what is worth to achieve and why [19].

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# THE MISSING LINK: CO-CREATION THROUGH DESIGN ENGINEERING PROJECTS

**Nigel GARLAND and Zulfiqar KHAN**
Sustainable Design Research Centre, Bournemouth University, UK

**ABSTRACT**

The Design Project units are the cornerstone of academic and professional development within the undergraduate Design Engineering programme at Bournemouth University. They provide technical, conceptual and theoretical challenges to be resolved through the integration of taught elements and self-directed learning to yield tangible outcomes. Final year students supplement their project through the Advanced Technology and Innovation unit. Here they work in conjunction with the research centres to develop understanding of a specialised discipline and write a research paper. However, students have limited time to develop before formulating a methodology while access to research facilities is limited and the learning curve for research equipment can be time consuming.

To address these issues, 2$^{nd}$ year students were asked to design a fatigue testing machine for use within the Sustainable Design Research Centre as a design project. Designing such a device provided students with a sound understanding of fracture mechanics at the beginning of the project, operation capability of test equipment, test methodologies and systems control; essentially they developed the prerequisite knowledge to engage in their 4$^{th}$ year research. Funding was secured from the University's fusion investment fund (co-creation strand) to provide flexible adaptable elements and construct a pair of exemplar fatigue testing machines reflecting those developed by the students. The familiarity through the inbuilt adaptability of mechanism, control and data acquisition systems allows for a rapid understanding of their operation and capability hence short learning curve with equipment prioritised for undergraduate research.

*Keywords: Co-Creation, Projects, PBL*

## 1 INTRODUCTION

In recent years, there has been a drive to integrate Research, Professional Practice and Education within our university's schools, research centres and teaching frameworks. More recently the process has been formalised through the development of the "Fusion" concept and is a central feature of the university's 2018 strategic plan [1]. The importance of the fusion concept to the university can be identified by conducting a frequency search of keywords and their derivatives within the strategic plan (Table 1) and yields insight to the university's general direction.

*Table 1. Bournemouth University Strategic Plan, Keyword Frequency*

| Keyword and Derivatives | Frequency |
|---|---|
| Research | 93 |
| Fusion | 77 |
| Learning | 45 |
| International | 39 |
| Practice | 36 |
| Business | 29 |
| Enterprise | 5 |
| Teaching | 4 |
| Global | 4 |

Within the context of the strategic plan, fusion is described as *"the combination of inspirational teaching, world-class research and the latest thinking in the professions which creates a continuous and fruitful exchange of knowledge that stimulates new ideas, learning and thought leadership"*. To reinforce this goal a Fusion Investment Fund is available and specifically designed to encourage the fusion of learning, research and professional practice through three specific strands; co-creation & co-production, staff mobility & networking, study leave [2]. For the Design Engineering programme, there has been consistent application of the Fusion concept through the Design Projects units at Year 1, 2 and 4. These have been predominantly related to niche design projects with community partners such as Poole Tidal Energy Partnership and the Bovington Tank Museum.

### 1.1 Design Engineering Projects

Design Project units are the cornerstone of academic and professional development for undergraduate Design Engineering programme students; These represent 20 ECTS credits at Year 1 & 2 and 30 ECTS credits at year 4. Students develop a solution to a project brief encompassing the design process described in BS8887 [3] and BS7000 [4] amongst others and meet the requirements of the Engineering Council's EC$^{UK}$ SPEC for accredited degree programmes [5]. The Project units provide technical, conceptual and theoretical challenges to be resolved through the integration of taught elements and self-directed learning to yield tangible outcomes. They also present an opportunity to develop relationships with commercial, industrial and community partners and can act as a test bed for new conceptual models and alternative learning methodologies [6-8]. For second year undergraduate students there are two primary projects, the first is typically a small mass produced product representing 35% of the unit with the second a larger niche project representing 45%. For final year students, the project is represented by a single work and complemented by the Advanced Technology and Innovation (ATI) unit; here students develop a deeper understanding of a specialised engineering discipline leading to a research paper.

Reviewing the performance of the 2$^{nd}$ year project unit and the 4$^{th}$ year ATI unit identified four key issues within the programme:

1. Students often perceive their 2$^{nd}$ year projects as academic exercises where outcomes have no relevance to their final year studies.
2. Final year students are time constrained to develop a deep understanding of their chosen discipline before formulation of methodology for their ATI research.
3. The learning curve for successful operation of specialised research equipment can be time consuming and operator error costly.
4. The use of research facilities is limited due to prioritization of access.

These four factors combine to make access to equipment for short duration projects unlikely with little opportunity for undergraduate use.

## 2 LINKING DESIGN PROJECTS TO RESEARCH

The issues identified within the ATI unit could be overcome by allowing the students to develop the pre-requisite knowledge and understanding at an earlier stage in their academic career, before they commence their final year. The problem is identifying space in the academic calendar to ensure adequate understanding of the technical field and methodologies alongside prioritized access to specialized equipment. The issue identified within the 2$^{nd}$ year projects, relevance to final year studies, can be addressed to simultaneously solve those issues identified within ATI by providing a design project where understanding of research methods is central to success. It is clear from experience that students develop an intrinsic interest in subject matter related to the design work they conduct, essentially forming an emotional bond with their product [7]. Harnessing these elements they adopt self-directed learning to acquire the pre-requisite knowledge required to successfully complete their projects, an essential skill they will require to develop as competent design engineers in the future. By designing research equipment, students will need to acquire knowledge specific to that research domain and the outcomes dependent upon that understanding. Pasman and Boess [9] explored the value of designing for research within the context of design students noting *"…making things for design is something design students and are experienced with, using it for in a research context could catalyze their interest in design research."* However, this is countered by Dowlen [10] who argues that *"We need to accept that designers being academic researchers does not work, in general. And student designers work even less well as researchers."* Although this may be the general case for "design" students, it can be argued that Design Engineering students can benefit from exposure to the experimental and bespoke nature of research with regard to their future roles as innovators or research and development engineers.

### 2.1 Project brief

To achieve the goals outlined above 30 Design Engineering students were asked to design a one-off test machine for conducting fatigue analysis in a cantilever configuration. Sample size was breadth: 5mm, depth 10mm, effective length 250mm and notched at midpoint to a depth of 2.5mm complying to the relevant standard [11]. Sample material constraints were not provided and students were therefore expected to design to suit a range of material types based upon available data.

### 2.2 Project rationale

The design process can vary with methodology adaptation to reflect project complexity, size, volume and value with both iterative and linear models [12]. However, the underlying process is essentially the same and described in general terms in BS8887 [3] adapted by the authors (Figure 1).

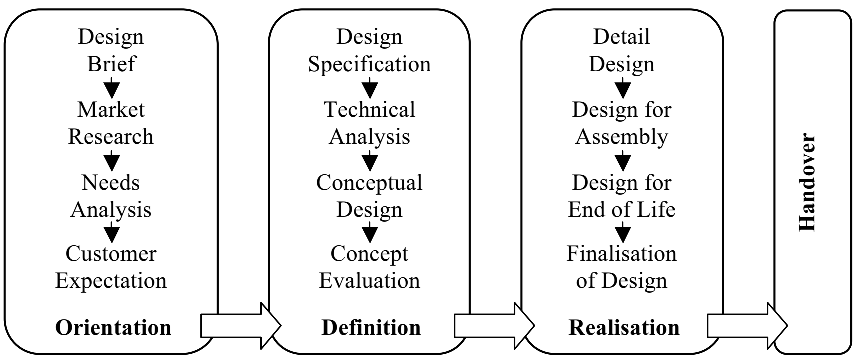


*Figure 1. The Design Process, adapted from [3]*

Working within the design process it is clear that students must first understand the market and conduct needs analysis to identify key design constraints for the product design specification (PDS). It is this translation process, from general terms within the orientation phase to the SI units of design specification, where the designer requires knowledge and understanding of the scientific principles. In the case of this project, they needed to develop an understanding of fatigue in order to predict key drivers within the PDS.

### 2.3 Design Specification Derivation

Students were provided a range of material specifications and many supplemented this with their own research. From these materials students identified the maximum load that the sample could support by deriving the maximum stress from the fracture toughness. Students then applied incremental test case loads to the material specification using the Paris equation to derive the number of cycles to failure [13]. By modelling the test specimen they were also able to predict a range of deflections for applied load case, hence system stroke length. Finally, by combining load and stroke they could derive energy and, in combination with operating frequency, power requirement (figure or flow chart showing the flow of information between equations and show a general spec). Typically, students identified the device should provide a maximum force of 1000N, maximum stroke of 40mm and operating frequency of at least 1Hz.

Students recognised that the operational function of the device would, in essence, be the reverse of the methodology for deriving the specification. In other words, the calculated design specifications would be the principle measurements to provide control, data acquisition, or both.

## 3 STUDENT DESIGN OUTPUT

Most students successfully completed the design project and identified key operational characteristics. At the conceptual stage students typically identified three to four potential working solutions before formally optimizing their final design. Solutions varied between students at both stages but can be grouped by technology both within the load application, measurement and control systems (Table 2). Examining the output there is a clear demarcation between rotary to linear drive systems requiring cams or cranks, whether directly or indirectly and solutions with loaded actuator based solutions. In the case of direct loading the cam or crank displacement translates directly to the sample. For indirect action solutions, the load would typically be applied with weights and the mechanism used to cycle this loading.

*Table 2. Technology Categorisation for Conceptual and Final Design*

| | | Design | | | Final Controls/DAQ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology | Concepts | Final | Viable | Load-cell | PLC | PC | DataLogger | Camera | Adaptable | Notes |
| Direct | Cam | 11 | 2 | 0 | | | | | | | |
| | Crank | 11 | 2 | 0 | | | 1 | | | | |
| | Scotch Yoke | 5 | - | - | | | | | | | |
| | Swash Plate | 1 | - | - | | | | | | | |
| | Cable | 3 | 2 | 0 | 1 | | 1 | | | | |
| | Any Direct | 15 | 6 | 0 | | | | | | | |
| Indirect | Cam | 20 | 4 | 4 | | | 2 | 1 | | 1 | PIC, Strain Gauges |
| | Crank | 12 | 1 | 1 | | | | 1 | | | |
| | Scotch Yoke | 3 | - | - | | | | | | | |
| | Swash Plate | 1 | 1 | 1 | | | | | | | |
| | Any Indirect | 23 | 6 | 6 | | | | | | | |
| Actuator | Pneumatic | 21 | 11 | 8 | 10 | 4 | 2 | 1 | 2 | 5 | Thermo-elastic Analysis |
| | Hydraulic | 12 | 5 | 5 | | | | | | 2 | |
| | Linear Actuator | 4 | 1 | 0 | | | | | | | |
| | Solenoid | 3 | 1 | 1 | | | | | | | |
| | Any Actuator | 26 | 18 | 14 | | | | | | | |

From the 30 students 26 proposed concepts with Actuators, 15 proposed directly acting motor driven concepts, 23 showed concepts indirect action while 29 proposed at least 1 direct/indirect solution. For the final design 18 students went forward with actuator based systems, the majority being pneumatic. 12 students chose to proceed with mechanical systems, of which only the indirectly loaded systems were adjudged viable. Within the context of control and data acquisition the most popular solutions were to use a PLC, PC or Data logger. Some students also proposed the use of infra-red imaging cameras to monitor strain through thermo-elastic analysis while others identified the benefits of flexibility that could be afforded by the use of adaptable T-slots within the structural elements. Examples of student work (Figure 2) show the typical general arrangement for the most popular configurations from which all except one student had proposed as a concept or final design.

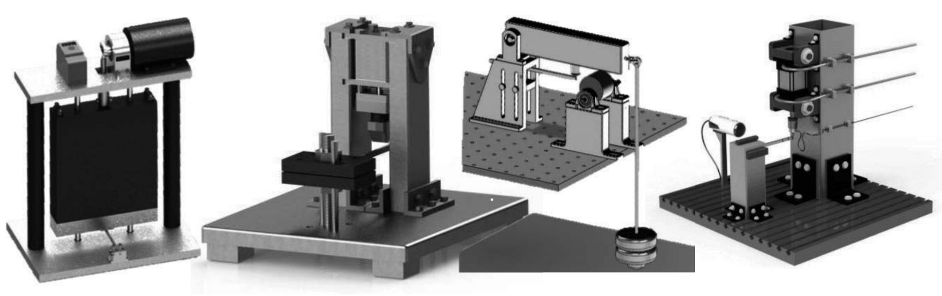

*Figure 2. Student Final Designs, L-R: Indirect with Counter, Pneumatic, Indirect with Adaptable Base, Pneumatic with Adaptable Base & I.R. Camera*

### 3.1 Project Learning Outcomes

Student learning within the project was achieved through self-directed PBL methods supported by key tutorials focused upon specific technical knowledge building. By channelling the project through specific technical discipline (Fatigue) students have built up a sound underpinning body of knowledge and experience of practical application. They now have a fundamental understanding of the practical limitations to the technologies explored; from a mechatronic perspective in the application of loading to the logical elements of process control systems and data acquisition. In addition, students have built an intimate foundation to the specifics needs of practical engineering research and how experimental apparatus can be derived from the goals of the research project.

## 4 LINKING TO FINAL YEAR RESEARCH

The fundamental issues hindering successful final year research work have been identified in the four factors described above. In the case of the factors 1-3 (Perceive relevance of $2^{nd}$ year projects to final year, time to understand discipline, learning curve for specialised research equipment) these have been overcome through the design project outlined above. To satisfy the fourth factor (prioritization of access to research equipment) funding was secured from the universities Fusion Investment Fund to provide students with access to their own equipment.

### 4.1 Equipment Specification

Rather than purchasing or constructing a specific fatigue testing machine it was decided to develop a set of configurable building blocks, or adaptable elements, that allow the students to rapidly construct equipment that reflects their own design and the methodologies they wish to employ. Examining the student proposals it was clear that two basic designs should be configurable (indirect loading and pneumatic) thereby encompassing the Conceptual designs of all of the students and the majority of their final designs. The kit comprises various components (slotted structural elements, pneumatic cylinder, loadcell, control valve, motor, eccentric, pulleys, motors, DAQ, PC, PLC, sample supports, linear sensors etc) from which two exemplar devices were constructed for the demonstration of system configurability to final year students upon their return from placement (Figure 3). The configurations meet the outline specifications derived from the students' project work with the pneumatic device operating at up to 10Hz, a theoretical maximum load of 1000N and maximum displacement of 40mm.

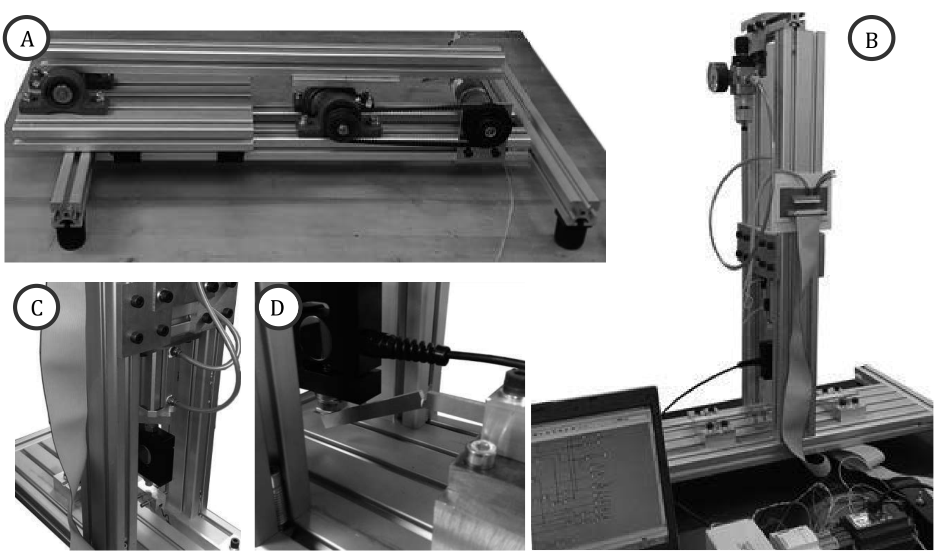


*Figure 3. Exemplar configurations: A, Indirect loaded; B, Pneumatic system with PLC and load-cell; C, 4 point loading; D, Cantilever loading*

## 5 CONCLUSIONS

The project, in conjunction with the development of the configurable elements and exemplars, satisfies the needs identified for both the 2nd year project unit and final year ATI. The project work itself allowed students to develop intrinsic interest in the subject area and knowledge of research methodologies (specifically in the area of fatigue and fracture mechanics) while satisfying their desire to design innovative engineering solutions.

The equipment, functionality and control systems described are derived from the students own designs, presenting familiarity of operation and capability. Students can now access hardware to build upon the foundations laid in the project, establishing a clear link between the two levels of academic study. These are adaptable in nature with a range of control options and framework elements presenting broader opportunities than the original cantilever scenario. They can be readily configured to directly represent the students own designs, presenting familiarity through the inbuilt adaptability of mechanism, control and data acquisition systems; this allows for rapid understanding of their operational characteristics hence short learning curve with equipment prioritised for undergraduate research.

Co-creation can be identified in two ways, directly through the co-creation of the physical hardware and through the co-creation of research outputs generated through the equipment developed.

The students draw upon and deepen their theoretical knowledge through practical application in the final year to the benefit of their academic development and future careers as design engineers.

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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# ETH FOCUS PROJECTS – SUCCESSFUL APPROACHES FOR PROJECT-BASED EDUCATION IN ENGINEERING DESIGN

**Marius STÜCHELI, Stefan BOËS and Mirko MEBOLDT**
pd|z Product Development Group Zurich, ETH Zurich, Switzerland

**ABSTRACT**
In the third year of the mechanical engineering bachelor programme, ETH Zurich offers so called Focus Projects as an integrative and intensive project-based learning course in product development. In this course type, interdisciplinary teams of typically 5 to 10 students in mechanical and electrical engineering and industrial design develop a product from the market profile to a tested prototype. From ten years of running Focus Projects and refining the course concept, three valuable approaches in coaching have been derived to increase learning and team performance. The presented reasons underlying the three approaches shall help engineering educators understand the importance of these approaches and give guidance in applying them on their own projects.
The first approach is factual and experienced feedback through extensive testing, which enhances the learning experience. The physical experience of the working of the own design adds meaning to the theoretical knowledge and thus leads to its manifestation. The second approach is value-based coaching, focussing on the values responsibility, transparency and open feedback. This helps the students grow not only on a knowledge level but as a person as they build self-confidence and learn collaborative behaviour. The third approach is the application of a question-driven stage-gate process. It gives the student teams the freedom to experiment and still enough orientation to reach a successful project outcome.

*Keywords: Project-based learning, testing, stage-gate process, coaching by values*

## 1 INTRODUCTION

Project-based learning is well-established in engineering education (see e.g. [1], [2], [3]). It trains the students in transferring theoretical knowledge to engineering practice, in soft-skills and in skills and knowledge like project management, presentation technique and technical documentation – skills that are not or little taught in other courses. A critical factor for the learning impact of a student design project is the coaching by the academic staff [4]. However literature specifically on the coaching aspect of project-based learning is scarce. The challenge is how to do the coaching to give the students orientation but still enough freedom to make their own experience, to try, fail and learn. In this context a big question for the coaching is, where to put the emphasis of what to discuss with the team and what to require from the team.

In the context of the Focus Projects we have developed three complementary approaches to coaching student teams towards intensive and comprehensive learning outcomes: Factual and experienced feedback through testing, value-based coaching and a question-driven stage-gate process. These approaches are not visible in Pembridge's extensive study [5]. They are applied in combination and proved to be successful with regard to both, the students' learning experience and also the technical project outcome.

We suggest these approaches to engineering educators running advanced design projects. To lay stress on the respective aspects of coaching requires consciousness for their importance. This consciousness is best raised when teachers understand the reasons why and the mechanisms how these approaches are valuable. To share these reasons is the goal of this paper.

The paper continues with an introduction to the history and the boundary conditions of Focus Projects at ETH Zurich. In the main part in Section 3 the three approaches are described together with the theoretical insights that underlie their application. Section 4 presents the conclusions.

## 2 FOCUS PROJECTS AT ETH ZURICH

The concept of Focus Projects was introduced at ETH Zurich in 2004 by Markus Meier, professor of product development at the Department of Mechanical and Process Engineering. The intention is to let the students apply their theoretical knowledge from lectures, combine it with a practical assignment and to experience the challenge of a real product development in a supportive learning environment.

### 2.1 General course setup

Since 2012 the Focus Project is an official course type that any professor in the mechanical engineering department can offer to mechanical engineering students in their 3rd year of bachelor studies. Some of the common characteristics are:

- 2 semester duration in the 5th and 6th term of BSc in Mechanical Engineering programme
- 14 ECTS for the project itself plus 6 ECTS for complementary courses
- Teams of 3 to 8 students of mechanical engineering plus students of other programmes

The general framework for Focus Projects also defines a list of common learning objectives [6].

### 2.2 Project diversity

Differences between the projects sponsored by different professors lie especially in the foci regarding

- the character of the project tasks, from technology demonstrators [7] over projects with industry partners [8] to world record attempts [9],
- the organization of the projects, like the teaching staff involved and the funding, and
- the emphasis and depth of coaching support (technical, process-oriented, methods) for the teams.

This year, 2013/14, twelve different projects have been offered by eight professors. Some projects are initiated from student ideas. The course allows including students from other faculties such as electrical engineering and also faculties of other universities such as industrial design. Additionally students from a business school cooperate loosely to conceive business cases based on the project outcomes.

### 2.3 Teaching and coaching structure

For the students doing a Focus Project, supportive courses are offered. One is a three day “base camp” at the beginning of the project for the students aiming at accelerating the team building process, catalysing the development of a project vision and introducing design thinking tools.

Two “practice courses”, of which the students can choose one, accompany the project through the first semester, one on project management, the other one on advanced CAD, PDM and FEM.

For the coaches, which are in most cases a team of PhD students and a master student who did a Focus Project earlier, a “coach-the-coaches training” is offered.

The organisation of most Focus Projects includes intermediate reviews and a final review. At these reviews the students present their project state, preliminary results and plan how to proceed in front of faculty staff and often also financial sponsors.

### 2.4 Focus Projects at pd|z

Due to the large diversity of the Focus Projects at ETH Zurich it would go beyond the scope of this paper to describe all variations. Therefore this paper focuses on projects sponsored by pd|z Product Development Group Zurich. pd|z sees humans in the central roles of product development, human users and human developers. Therefore it consciously observes roles and relations in the focus projects and strives for continuous improvement. In this context we have identified three successful approaches to coaching student teams that go beyond common coaching practice at universities.

## 3 THREE COACHING APPROACHES

In this section the three complementary approaches to coaching an interdisciplinary design project are described and explained. Examples base on the 2012/13 project “Ship Inspection Robot”. The project task was to develop a remote controlled rover that can move through the ballast tanks of cargo ships to take pictures for visual inspection of the ship. To that purpose the robot has to be compact, be able to drive on vertical surfaces or even upside down on the ceiling and also be able to overcome stiffening structures of different shapes (see Figure 1, Figure 2 and [10]).

*Figure 1. Final prototype of the exemplary project Ship Inspection Robot*

### 3.1 Extensive and systematic testing

No product development is finished with a CAD model delivered and no serious company would start selling an untested product. Testing is an integral aspect of product development [11] and what is more it is a valuable source of feedback to the students. Therefore pd|z puts strong emphasis on the testing of the students' systems (see also [12]). While many publications about student projects mention prototypes or testing (e.g. [13], [14], [15], and [16]) it remains unclear to a reader in what form and depth it is done and with what motivation it is promoted by the project coaches. The testing of the example project comprised many verification tests of single functions like wireless data transmission, correct and precise position control of single wheels or the defined turning of the camera. The most important test on system level was the passing of all defined obstacle shapes in four different directions to gravity (see Figure 1).

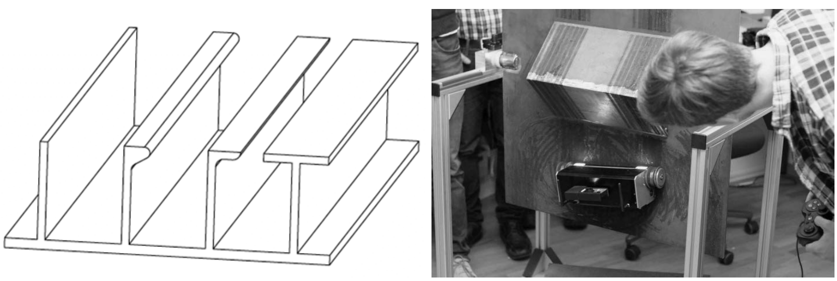

*Figure 2. Defined profiles for the robot to climb (left) and the turnable test rig, with which all relevant obstacle features can be simulated with variable direction of gravity (right)*

#### 3.1.1 Factual and experienced feedback

In education students usually get feedback on their work from their teachers based on the teacher's experience and opinion. Extensive and systematic testing can provide the students self-generated factual feedback in which no teacher opinion is involved: The students design and build a system, the students test it and the system does or does not what it was intended to do. The result of a test leads generate direct feedback on the students' assumptions and design decisions.

Important in addition to the factual component of testing is the experience component. When the students do the assembly they haptically experience how tight a chosen fitting is. And when they see the robot flip around a profile edge, and fear for a second that it would fall down, they can link the abstract idea of an instability point to an experienced situation. This physical experience helps the students give their theoretical knowledge more meaning and the emotional component of an experience leads to more intense and durable learnings. On the other hand testing helps the students to understand "the difference between theory and actuality" [17].

#### 3.1.2 Implementation and reflection

Most important towards implementation is probably the appreciation of testing by the coaches in general, leading to early questions about the plans how to test and late questions about the results of

the tests, as well as support in developing the test plan. More technical preconditions are that the teams have sufficient resources to build high fidelity prototypes and test environments and that the project definition allows for reaching a sufficient project maturity to be able to test the system.
For the learning effect it is also important that the students feel committed to the requirements that are tested. If the requirements come from the teaching team or a corporate partner, it is important that the students understand the reason behind them and adopt the requirements as their own. In our observation, projects pushed towards extensive testing achieved higher project maturity at the end of the project.

## 3.2 Coaching by values

In long-duration student projects that include an intense coaching by teaching staff, the input and the attitude of the coaches have an impact on the students' motivation and behaviour throughout the entire project. By trying to get the best benefit for the students, we are focussing especially on the process, how methods and approaches are taught, how the interaction occurs and how beneficiary mindsets can be passed on to the students. This can be done effectively through communicating and exemplifying values, which help the students, grow, not only on a knowledge level and for the current project, but also as a person for future challenges. Adopting these values further helps the students improve their collaborative skills.

### *3.2.1 Open feedback culture*

In an environment of young motivated students and engineers, the willingness for learning new things and for personal development is very high. The feedback from teammates and coaches is highly valuable for the reflection process. Therefore it is important to demonstrate the value of open feedback culture to the students. This is firstly done by giving feedback to the students in a constructive and positive way, so that the image of giving feedback is attractive and positive. Especially the feedback framework "I like, I wish" – consisting of positive observations and constructive suggestions – enables a positive view on feedback, which is in our culture often but misleadingly put on a level with negative criticism. Secondly an openness to give and receive feedback is presented and regular feedback sessions are organized.

### *3.2.2 Taking on responsibility*

For students in the 3rd Bachelor year with little project and teamwork experience, it is an important aspect to build up self-confidence in their own abilities as a future engineer. We believe that this can be achieved by giving them many rights and freedom for their decisions on goals, requirements and the way of achieving them. As coaches we encourage them to take on responsibility by, for example, defining the deliverables expected from each team member in his respective role. Major decisions are left to the team and help is just offered for example by working out the pros and cons for a decision together, but never by deciding for the students.

### *3.2.3 Transparency – no hidden agenda*

In our opinion the ideal role of a coach, how he is recognized by the students, is an engineer with some more project and product development experience compared to the students and who gives helpful input and hints whenever possible. To support the team effectively, the coach should have insight in the technical aspects of the projects and the team dynamics. The students will only grant this insight, if they do not perceive a coach as a judge or as someone having a hidden agenda. For helping the students accept this role, the underlying goals and ambitions need to be communicated clearly and transparently. It is important to be open about the fact that the coaches are not experts in everything. In this context it helps to talk about the coaches' careers to the students to help them judge how well-founded an input from a coach is. Transparency between coaches and team should also lead to the same openness within the team among the students. This ideal of "no hidden agenda", of as much transparency as possible, is addressed openly and directly from the beginning.

### *3.2.4 Implementation*

After the selection process for students wishing to attend the Focus Project course, the project starts with a kick-off event together with both students and coaches. The goal of this event is to manage each other's expectations for the upcoming year and learn about the respective roles. The coaches present the values of pd|z and also their values in coaching, such as transparency, trust, responsibility, open feedback and willingness to learn. They make examples on how those values express in daily routine and what consequences they have for the coaching relation. In the weekly coaching sessions the coaches are very careful to act according to the values and sometimes refer to them, to continuously make the students aware of what motivates their actions.

## 3.3 Question-driven stage-gate process

It is common practice to divide projects into multiple phases and to define milestones when certain tasks have to be completed. This also applies to education projects. When the milestones do not only define a deadline but a decision point, they are rather referred to as gates [18]. Often in such processes in education the milestones are deliverable-driven (e.g. [19]). This approach has three traps:
Firstly, every development process is unique and characterized by specific challenges [20]. Fixedly defined deliverables based on certain tools, like an FMEA analysis or a critical function prototype [17], or with a specified result, like a market segmentation [18], are often not apt to solve the effective challenge at a current project stage. Secondly, engineering education should not aim at educating "executors" but at educating actively thinking team members and "leaders" in engineering. Thus it is desired that the students reflect on the product development process itself. Fixed deliverables do not foster this reflection. And thirdly, rather openly defined deliverables like a "product profile" [16] run the risk of not answering the relevant questions for a gate decision.
To reduce the risk of stepping into one of these traps we promote a question-driven stage-gate process.

### *3.3.1 Question-driven approach*

Instead of fixed deliverables the framework given to the students defines what questions have to be answered at the gate to support a well-founded decision. But it does not define *how* these questions should be answered. Examples for such questions are: "Are the selection decisions coherent and well-founded?" (standard question at all gates) or "Are the technological risks known and the critical functions identified" (gate 2: "product concept"). Thus the team can define for themselves what they plan to do to answer the gate questions. As a suggestion, "typical" tasks and methods for every stage are provided, however it is not compulsory for the students to use them.

### *3.3.2 Compromise between orientation and self-direction*

We believe that a question-driven stage-gate process is a good compromise. On the one hand the gate questions give orientation to the development team. The answering of the gate questions forms an intermediate goal. To be successful in answering the critical questions at the gate also helps to reduce the risk of big mistakes provoking big and thus "expensive" cross-gate iterations [20].
On the other hand the question-based framework leaves great freedom to the development team, in what form to answer the gate questions. Especially it allows to experiment and to adjust the choice of methods to the specific characteristics of the project, for example the knowledge base from which the development starts and the resources available for the project.

### *3.3.3 Gate scheduling*

In contrast to common corporate reality the Focus Project teams are given the freedom to schedule the gates, and thus the stage duration, on their own. In case the plan looks completely unrealistic the coaches can give feedback to the planning. What is more important, however, is the experienced feedback the students get on their planning from how well they manage to follow it. This is again a factual and experienced feedback like the one obtained from testing (see Sec. 3.1).

### *3.3.4 Implementation and reflection*

The board deciding whether a gate can be passed consists of the direct coaches and the professor. The meeting is prepared by the students with a two page summary of the project state and the answers to the gate questions. After an informal presentation by the students and additional questions by the board members, the latter decide on whether to let the team continue as planned or to require more or better answers.
It is still a challenge to achieve that all team members and throughout the stages work with the provided framework. In our observation, mainly the students dedicated to project management use the framework document intensely and that mainly when it comes to planning the next stage.

## 4 CONCLUSION

This paper presents three complementary approaches to coaching a design project in engineering education:

- Systematic and extensive testing to induce factual and experienced feedback,
- coaching by values to train them in responsibility and self-confidence and
- a question-driven stage-gate framework providing flexibility and freedom to experiment.

These three approaches support an intense and genuine learning experience as well as personal growth for the students in the scope of the two semesters Focus Project. The approaches are not unique to project-based education, but it is their explicit and conscious application which makes coaching more valuable. The understanding of the underlying reasons, presented in this paper, helps coaches to implement the complementary approaches consequently and in the coaches' individual style.


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# NEW TEACHING DESIGNS APPLIED IN ENGINEERING SCHOOLS: AN EMPIRICAL CASE STUDY ON NON TECHNICAL SUBJECTS

**Anderson Edilson PRESOTO, Lucas BALDICHIA, Ana Lúcia Figueiredo FACIN, Roberta SOUZA and Isabela Mantovani FONTANA**
University of São Paulo, Brazil

**ABSTRACT**
Brazilian public universities, in particular, engineering schools, have been founded inspired by European models: students following a learning process in a passive mode, where knowledge is transferred from professors in a one oriented way. The aim of this paper is to discuss about pros and cons of experimental methods on non technical subjects taught in engineering practices, once the approach normally adopted in these situations differ from engineering courses logic, where praxis is at stake. To achieve that, an empirical case study is done, at Polytechnic School of University of Sao Paulo, using a classroom experiment in economics science. The experimentation dealt with Competitive Equilibrium, one of the most central concepts in microeconomics. The results indicates that this is an efficient method based on satisfaction and academic score indicators which shows stronger integration of students on Managerial courses, requirement that has been highlighted in the last years. This learning proposal appears to encourage proactive behaviour from students, building their own knowledge. Moreover, this case study helped to evaluate assumptions of neoclassical economics on the presented topic (Competitive Equilibrium) and point out aspects that cannot be directly related to the neoclassical approach but to other economic theories. In this case, the linkage between different economics approaches could be widely explored. Nevertheless, some weaknesses must be mentioned as for a natural resistance to change must be faced. Going further in this trade-off appears to be the questions that researchers on design to engineering education will face and this paper explores.

*Keywords: Design to engineering education; new teaching designs; learning proposal*

## 1 INTRODUCTION

Brazilian public universities, in particular, engineering schools, have been founded inspired by European models, including the Portuguese model, since higher education has its roots in the imperial period, as well as the French and the German model ([1], [2]). In all of these models students follow a learning process in a passive mode, also called "chalk and talk", where knowledge is transferred from professors in a one oriented way. This models is more linked with Socratics methods, instead of scholastics ones. This fact is also evidenced on the research conducted by Michael Watts [3], in which the "chalk and talk" style still predominates in courses related to economics, the author emphasizes that other teaching methods have been employed with increasing importance.

In this line, the Brazilian university model has also been questioned. This phenomenon may be clearly noticed at Polytechnic School of University of Sao Paulo, one of the biggest and better evaluated universities in Latin America, according to different international rankings, such as Times Higher Education and QS ranking. Recently, this traditional engineering school revisited the curriculum inspired by the motto "greater flexibility in the careers" and a new curriculum system was proposed to the engineering students who will be free to choose part of their courses.

It is undisputed that the engineering education is confronted by the challenges of globalization, inseparable phenomenon of recent decades. By observing the practices adopted by universities with high quality standard, it is punctuated [4] the need for inclusion of managerial disciplines in the curriculum of engineering courses. In this way, students gain a greater understanding could incorporate problems linked to the characteristic engineering projects, developing industry related skills [5]. In the Brazilian context, this outlook is not different. In the top five engineering schools in Brazil, in all their courses, managerial disciplines such as introductory economics and principles of management are offered.

Although concepts of economics are universal, their approach depends on the context in which they are discussed. It is punctuated [6] the difference in teaching economics to business students and engineering students, as for the differences in mathematics teaching in these two contexts [7].

Regarding the teaching of the discipline of economics, teaching methods have been widely discussed, especially with regard to the use of resources which aim to achieve that students are actively involved in the learning process ([8], [9], [10], and [11]). A more active teaching system is widely discussed in the scientific literature, such as economics experiments, games or other interactive activities. Virtual activities are as well discussed ([8], [9], [10], [11]).

Taking into account these considerations, a question arises about the efficiency of experimental methods. Although there are many studies reporting the experience using innovative methods ([8], [9], [10], [11]), few approach the efficiency of these new methods. According to research carried out in the ISI Web of Science only twenty articles with topics on "efficiency" and "teaching methods" were found.

Although the pertinence and relevance of this matter, this paper is not concerned with strong considerations on pedagogical aspects. The focus is on new teaching designs applied in engineering courses. The aim is to discuss about pros and cons of experimental methods on non technical subjects taught in engineering practices, once the approach normally adopted in these situations differ from engineering courses logic, where praxis is at stake.

To achieve that, an empirical case study is conducted, at Polytechnic School of University of Sao Paulo, using a classroom experiment in economics science. The experiment dealt with Competitive Equilibrium, one of the most central concepts in microeconomics.

This article is structured in five sections. Section 1 presents the context and purpose of the research. In section 2, the theoretical background of the research is presented, focusing the theory that is the basis of the experiment. Section 3 presents the details of the experimental method used in the case study. Section 4 presents and discusses the main findings of the research. Section 5 provides the main findings of the research, followed by the interpretation of the main results. And finally the contribution to the field of research studied, as well as the limitations of this research.

## 2 THEORETICAL BACKGROUND

To understand Competitive Equilibrium, is vital to introduce what is behind the traditional economics theory. With the aim of understating the logic adopted in experimental method, in this session, this theme is briefly discussed. A special attention is given to the assumptions of this theory. This will be significantly important to evaluate if the experimental method adopted is efficient or not in keeping this assumptions.

The firm from the perspective of traditional economics theory is understood as a “black box”. In this sense, the firm is perceived as just a production function and it is neglected the relation inside and outside firm, its origin and why still exists or not. Taking this in mind the economics theory develops the concept of competitive market, as a kind of market structure. According to Mankiw [12] competitive market is a “market with many buyers and sellers trading identical products so that each buyer and seller is a price taker”.

Perfect information of all economic agents, large number of small firms, firms can free entry and exit, and homogenous product characterize the competitive market according to the traditional economic theory. In this structure, the agents are not able to influence price or quantity of market, which implies that they are price takers. Besides, the agents’ revenue is proportional to the amount of output produced and, in order to maximize profit, a firm chooses a quantity of output such that marginal revenue equals marginal cost. Consequently, the supply curve is the firm’s marginal cost curve. This happen because of the large number of agents and the difficulty to organize themselves in order to interfere in the market.

According to Demsetz [13] the marginal product value of one input is a function of only one controllable variable, that is the quantity of inputs. In this case, elements such as price, technology and work quality does not affect productivity. The quantity is the only variable considered in the manager decisions.

## 3 EXPERIMENTAL METHOD

The case study procedure was conducted following Ruffle's recommendations [14]. A total number of 56 chemical engineering students, who had never had a formal contact with economics concepts, took part in the classroom experiment performed in one of the "Introduction to Economics" lectures.

Due to human resources and physical location constraints, two different blocks of students underwent the experimentation simultaneously in the same room but effort was made to avoid any communication between them.

Each block was further split up into two different groups of the same size, one representing the buyers and the other, the sellers. All students were tagged in a manner that sellers could visibly be distinguished from buyers. The tagging done, the experiment was able to be further carried out.

From this point on, the experimentation was run in rounds. In each round, buyers and sellers were physically separated and a single card was given to each student containing a value which represented his/her utility. A buyer could only negotiate one single unit of some sort of product with a seller, who could in turn sell his single unit of the product. Thus, the cards that sellers and buyers received had different meanings: for buyers, the value represented the maximum amount of money they could spend on a product, while for the sellers, the number defined the production cost of his product and they could only sell his unit of production for a value greater than that displayed on the card.

The students were informed not to tell his/her colleagues about the values received and could only start the negotiation after a pre-defined command. Negotiation occurred in a pit market and the round could last no more than a pre-established period of time.

Ended the round, sellers and buyer who had agreed upon a price should inform the supervisors about the accorded value. Those who didn't make a deal should also report the instructors. All the cards should be returned to the instructors and mixed up in order not to give the same buyer or seller the same card every round. Profit for every participant involved in a negotiation was calculated in every round: for buyers it was the difference between his/her amount of money and that agreed while for sellers it was the difference between the agreed value and the production cost. Profit, participants' ID and agreed price were recorded in an Excel spreadsheet before the beginning of a new round.

## 4 RESULTS AND ANALYSIS

The analysis proposed in this article goes in two different axis. The first one focus on the didactical aspects, whereas the second one will regard the economics learning results. Two questions about the former axis will be discussed: satisfaction perceived and alleged by the students and resources deployed with the teaching method applied in the experiment. The later axis, in turn, concerns two other questions: the retain efficiency of learning economics concepts and the capability of experimental methods to treat these economic concepts.

Normally, the use of different teaching methods is evaluated by the students' satisfaction service. Adopting this same approach, it was measured the students' satisfaction through five Likert based questions during different moments in the course. In particular for the proposal of this article, it was surveyed the satisfaction one class before in which was employed the traditional method of solving exercises and surveyed again after the experiment conducted in the classroom. The evolution of the results is summarized on Table 1. The total of ten questionnaires, filled by five people each, was collected.

*Table 1. Results of the satisfaction survey with students*

| Item asked to students | Before Experiment | Post Experiment | After Experiment |
|---|---|---|---|
| Scope of the exercised contents | 4.25 | 3.50 | 4.09 |
| Opportunity to review the concepts studied in lecture | 4.15 | 3.40 | 3.92 |
| Development of team activity | 4.06 | 3.90 | 3.82 |
| Temporal extent of activity | 3.40 | 3.10 | 3.62 |
| Dynamics of activity | 3.40 | 4.30 | 3.32 |

According to results show on Table 1, it is undeniable that difference can be noticed. Statistics tests goes in the same direction revealing significant differences between the ‘traditional activities’ and experiment. By one hand, the proxies that measure dynamics of activity have a improvement. By the other hand, students are very clear with their unhappiness with the time expended by this activity when compared to traditional ones. Reinforcing the results, is important to mention that the standard deviation is significantly high. The variance coefficient is impressive 0.49, showing inconsistent and no uniform results.

The results observed on satisfaction are consistent with the findings that are likely to be found in the literature on the subject: students that seek more dynamic and interactive methods. However these results abetting a given data revealed by this research. Students are reluctant or even resistant to proposed changes. This can be evidenced by observing the qualitative assessments made at the end of the experiment, where they were questioned about the ability of the experiment on students' learning process. Results can also be noted that the first and second proxies in Table 1.

Among the 5 proxis adopted, only the criteria related to dynamics increased with experimental method activity. Regarding the other four measures, the results go against this line. It is possible observe a generated decrease in all these values. The stability of these figure may be noticed when the results from the first traditional activity was applied (before the experiment) with the results from the traditional activity after the experiment.

An important aspect is usually ignored: the need for additional resources in terms of materials and people. During the experiment were there the professor, assistant professor and three guests, thus overcoming the resources expended in a traditional classroom. Besides human resources, it’s important to include material resources just for this experience, more than 300 printed pages and cards were consumed, plus technological appliances. Even these methods bring benefits to the students, it’s relevant to highlight the reality in different Brazilian universities it's not the same from the University of São Paulo, which counts with highest university budget in Brazil. Hence, adopting this different approach implies an additional challenge: capture the resources needed.

When asked about the effectiveness of an educational method, one should not focus only on the aspects already discussed. One must keep in mind that the educational approach aims to enhance the education of students. Given this caveat, it is also crucial to note is after the experiment students were able to absorb the concepts that were being addressed by this method. In this case, as outlined in the theoretical background, competitive balance was the concept behind the experiment. To assess the level of understanding of students in the final assessment they were asked, in a very simple and direct way about the experiment. Precisely the following research was called: "The experiment conducted in the classroom had a well-defined goal. What was the point of it? Which concept (s) was (were) tested? How it was possible to check if the goal has been reached? What the preliminary results indicated? What factors could have led to different results from those that were expected?” The correction of this question followed the following rule: each correct statement about the experiment the student received the score of 0.1, with a maximum score of 1.0. The correction was performed by the assistant professor and reviewed by the teacher. A total of 58 took the test and all were present on the day of the experiment. It is worth mentioning that the adoption of this mean was motivated by the seriousness with which students perform a test.

The results indicate a deficiency in the capacity to absorb the contents treated there, with a score of 0,27 (27%), with a standard deviation of 0,25, clearly shows this deficiency. The students had significant difficulty in understanding the theoretical foundations of the experiment, associating them with solids contents that had been explored in lectures, as well as interpreting the results that were submitted after the experiment session. A comparison with the overall average of the final test results confirms this finding. The overall performance was higher than the specific performance question about this experiment (48, 6%). It would still be possible to compare the result with the middle term test (65, 5%), the results of which were more significant than those obtained.

Moreover, it is interesting to analyze if the experimental method is actually able to test, via a practical approach, theoretical concepts. In this particular case, to test the operation of a market in perfect competition. It is known that experimental approaches have limitations such as the inability to reproduce real situations under which the theory speaks of. The experiment conducted in this study, as already highlighted, is about assumptions of neoclassical microeconomic theory. These assumptions define specific behaviours, whose disobedience may result in distortions in the expected results. This is a already much debated and questioned theory. Williansom [15] debates these assumptions by inserting the variables of bounded rationality, imperfect information, uncertainty, and other variables that define transaction costs as defining elements of the behaviour of market players who were ignored by neoclassical theory. It is worth to question whether an experiment conducted in the classroom is able to discern specific aspects of a theory alone, disregarding the influence of other variables, already widely exploited in defining the behaviour of market actors. The intention here is to raise the discussion of the efficiency of the experimental method to study this specific topic, knowing that the result may be biased by a number of factors. In this specific case, the goal would be met if the experiment were able to isolate these variables, exactly fulfilling the assumptions of the theory underlying the experiment.

However, require the students explicitly or implicitly such an attitude is something significantly difficult, or even impossible, since we are dealing with students of a course in introductory economics. This difficulty can lead to a paradoxical situation where the results distorted by the failure of theoretical assumptions leads to confusion as to the students' understanding of concepts. In the specific case, variables that are widely exploited in heterodox theories of economics, as a previous relationship, uncertainty, friendship, incomplete information, were decisive for the result not reaching the walrasian equilibrium. Thus, students were faced with concepts that fled to what was being examined by the experiment. Clearly, more robust models of such experiments could isolate variables in a more particular way, but more sophisticated and expensive resources would be needed. Therefore, experimental methods, as the one adopted, not necessarily fulfil the objective of delineating, because of the significant difficulty of keeping under control variables that are unknown by the students themselves.

Last but not least, is valid to highlight a last finding observed through a qualitative analysis. The introduction of new methods, such as adopted, requires a change of attitude, a change of behaviour. To do so, a break with centuries-old tradition should be taken. Students pass from a passive mode to an active mode in, which can be considered, an abrupt way. It is necessary, therefore, an effort to track possible dispersions, riots, discouragement, disruptions or any other form of shambles. In a situation where an only teacher had just come into the existence of several regents. How to make everyone stay in harmony, is a considerable challenge.

## 5 CONCLUSION

Many challenges arise when changes in teaching methodology changes. This article aimed to discuss the efficiency of experimental methods in teaching introductory economics for engineers. The attempt was to approximate the teaching of non-technical disciplines to the reality and characteristics of this kind of audience. The main question was to precisely evaluate the efficiency of alternative methods, focusing on the experimental method to this profile of students.

The experiment replicated in this study addressed the concept of competitive equilibrium, a central concept in microeconomics study, grounded on a number of assumptions. To answer the question that was posed in this article, a case study was conducted with students in an engineering course at the University of Sao Paulo.

The efficiency in this study was analyzed in different perspectives and the results were not inspiring. The assessment, as perceived by the students, indicated that satisfaction, in terms of dynamics, had an increase, albeit small, in the levels earned. The results were consistent with the literature on the subject. However, when students were asked about coverage, capacity concept review, among other issues, the results were not satisfactory. In general, there was a reduction in the degree of satisfaction of these variables at the time of application of the experiment.

Moreover, analyzing the capacity of absorption of the contents by the students treated in the experiment, measured through official assessments applied to determine whether to approve or not the student in an activity that commonly that involves greater commitment and seriousness from the students, the result was clearly insignificant. With a level of achievement of 27%, this number is well below the yield constant in other reviews or even on total of their evaluation.

Other observations can be punctuated as for the significant need for additional resources, the involvement and collaboration of students and the clear violation of theoretical assumptions, something difficult to control in the conducted experiment. All these matters lead the validity and applicability of these methods, as they are currently applied at universities that aim to achieve higher parameters in terms of quality.

Clearly this study has its limitations, such as the restriction to a single case study and no further discussion of pedagogical issues. It is suggested expanding the study and developing additional proxies that measure the efficiency of these methods.


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Chapter 15

# REFLECTION ON TEACHING

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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# SUSTAINABLE DESIGN TECHNOLOGY: A CASE STUDY OF A MASTER STUDENT'S LAMP PROJECT

**Arild BERG, Einar STOLTENBERG and Janne REITAN**
Oslo and Akershus University College of Applied Sciences

**ABSTRACT**
Creatively treated materials from nature transform, through technological processes and design practice, into cultural objects containing function and meaning. Views on nature, culture, and technology are gradually in a process of change and thus contribute to new practices. Multidisciplinary, innovative thinking within the Norwegian forestry industry has led to new, aesthetic experiences in nature that might influence product-design thinking. Forestry business with complex technologies has been linked in various ways to the built environment, architecture, and design. The research question of this study was: how sustainable products can be developed through an innovative combination of nature, culture, and technology in a master student project? This was illustrated through a case study of a master student's development of a lamp design. The product included semantic references to old woodworking techniques and cultural heritage, and evolved to an innovative product with commercial success. Methods used were document analysis and participatory observation. The product has contributed to a marketing strategy of corporate, social responsibility for the Forest Owners' Association. Students can get an expanded view of how design practice can be seen as an integral part of a sustainable worldview that includes both self-realisation and commercial realism. The learning outcomes from this study are related to knowledge, skills, and general competence.

*Keywords: Forest ecology, sustainable design, cultural heritage, design literacy, master study*

## 1 INTRODUCTION

At the meeting point of nature, culture, and technology a design object may emerge. Creatively treated materials from nature transform through technological processes into cultural objects containing function and meaning. A technological focus [1] does not always reflect a market showing renewed interest in products expressing nature, culture, and traditional production methods used in new ways [2]. Products related to handicraft traditions and cultural heritage have experienced a new renaissance in the design market.

## 2 BACKGROUND

The forestry business and wood technology have been linked in various ways to the built environment, architecture, and design, and the timber industry is constantly on the lookout for new industrial opportunities. Views on nature, culture, and technology are gradually changing and thus contribute to new practices. An example is Arne Næss' eco-philosophical view on nature [3]. This is a holistic worldview based on an ecological understanding of the world and the individual's place in this world. This could lead to design practitioners being influenced to make products that reflect such values.

### 2.1 Design and consumerism

In the research project Design Literacy (from primary education to university level), of which this paper is a part, the main purpose is to further develop knowledge of design education. Design has a wide impact on society, seen from a consumer perspective in light of sustainability issues [4]. Design education (from primary to university level) is, in this project, regarded as a key issue for developing a sustainable society, as choices made by the general public when it comes to design, touch the core of consumerism. Designers, decision makers, investors, and consumers hold different positions in the design process, but they all make choices that will influence our future environment.

### 2.2 New sustainable thinking in the forest industry

Another practical result from ideas on sustainability [3] can be found in forestry where natural fallen trees, to a large extent, are left to decay to enrich vegetation identity and species diversity (Figure 1A). In addition, standing dead trees from deciduous trees and old pine are left after logging. This multidisciplinary, innovative thinking towards sustainable forest management within the Norwegian forestry industry, has led to new aesthetic experiences in nature. Several organizations had worked towards such sustainable forest management, but a Norwegian standard was first agreed upon in 1998 when the Living Forests [5] concept was established. Involved in the concept were stakeholders in forest management and the forest industry, environmental and outdoor recreation organizations, trade unions, and consumer interests. The standard has been revised several times and is currently located under the international forest certification system, Programme for the Endorsement of Forest Certification (PEFC) as the Norwegian PEFC Forest standard. An interesting part of Living Forests is that this holistic focus on sustainable forest management includes aesthetic perception of nature.

### 2.3 Design semiotics: the meaning of design products

Another understanding of environment on a product-design level is reflected in theory on product-design semiotics by Rune Monö [6]. He describes the elements of logic whole in design as the idea, function, ergonomics, and aesthetics that come together as product semantics. He claims that the meaning of design products has to be understood in relation to pragmatics and syntax as demonstrated in his product semiotics. This theory contributes to the students' holistic understanding of the design process through defining design elements, placing the design in a context, and relating it to similar designs. However, in a sustainable tradition [3] this is a too narrow theoretical standing point for design, because in order to see design products as a part of a larger system, a specific holistic view of the world is needed.

### 2.4 Sustainable perspectives

In an expanded view on design theory, nature and environment are relevant factors. In the search for such a constructive relation between theory and practice in design theory, it might be useful to learn through a qualitative study [7] from related fields such as architecture and urbanism. This has been exemplified in art seen as a part of the environment, not only from an urban perspective, but also as public health from a holistic perspective [8]. Critical Realism [9] can be seen as a relevant approach in this context, because design studies require interdisciplinary integration, an appropriate understanding of relationships between human actions, and physical artefacts, and a possibility for making "soft", qualitative predictions about likely impacts of proposed solutions. It has been claimed that critical realism matches these requirements better than many competing positions within the philosophy of science [9].

Critical realism not only welcomes interdisciplinarity, but also considers, for ontological reasons, interdisciplinary integration as necessary in arriving at valid knowledge. Critical realism's conception of causality, where causes are understood in terms of the generative powers that things may have, means that designed artefacts also hold causal properties. This is exemplified in the enabling or constraining of human actions or triggered perceptions to which the individual may attribute aesthetic value. The artefacts are also liable to be influenced by other causal powers, including the actions of human agents. The causal influences, as seen in critical realism, are not deterministic. They may be counteracted or strengthened by other causal mechanisms operating at the same time. They should therefore be understood as tendencies, not as constant conjunctions. This way of understanding causality makes it possible to make sense of the ways in which designed artefacts matter to people by being useful, beautiful, ugly, impractical etc., and also how new designs and materialised artefacts can be developed and created through human agency. Moreover, a critical, realistic view on possible research-based predictions squares well with the qualitative impact assessments of alternative solutions and the modest, context-adapted estimates of how a designed artefact is likely to fulfil its intended functions be they instrumental, symbolic, or aesthetic. Opportunities from within these standpoints may be detected for the field of design education, as they signify basic new ways of thinking regarding design practice.

The research question was how sustainable products can be developed through an innovative combination of nature, culture, and technology in a master student project. A master student project was chosen because it was relevant, at hand, and useful for learning outcomes that were achievable. The aim was to identify realistic learning outcomes [10] for product-design education that emerged from a student practice which also had proved to be a business success.

## 3 METHOD

The research question was explored through a case study [11] of a master student's development of a lamp design [12]. It was possible to learn from this approach and through theoretical perspectives that enhanced the validity of the findings [13, 14]. The product included semantic references [15] to old woodworking techniques and cultural heritage [16], and evolved to an innovative product commercialised and sold by Bolia Furniture Company. There was documented analysis of the student's master's report, practice report, magazines, and web sites that presented the product [11]. Data was collected through participatory observation in supervision of the student. Categories were identified through concept mapping [17] and pattern matching [11] in relation to the presented, initial theories of product semiotics [15], Deep Ecology [3], and critical realism [9]. The aim was to expand the understanding of elements of these theories through analysis of a practical, student-design project [14].

## 4 RESULTS: REFLECTIONS FROM A MASTER STUDENT

The reflections are documented from the student's master projects, highlighting some relevant categories:

*Figure 1 ABC: A: Living Forest. B: Woodwork bench C: The lamp Turn, by student Caroline Olsson*

The student was fascinated by old woodwork techniques that she thought were connected to cultural heritage and noble, handicraft traditions: *The lamp was inspired by the old workbench (Figure 1B) often used in wood workshops in Norway.*

Emotional recognition: *There was a product line in my study where products were connected to each other through the use of associations, materials, colors, and working method…*

Conceptual representation, emotional recognition, and branding: *During the project there has been a desire to promote a stronger relationship between the products and what is around the brand "Caroline Olsson". Concerning media exposure it is not always easy to control what the outcome will be. A valuable marketing example was when the lamp "Turn" (Figure 1C) was pictured in the design magazine "Wallpaper"…*

Corporate social responsibility, conceptual representation, and self-realisation: *Other examples were the products pictured in the journal "Skog" [Forest] promoting ideas on how the forest could be used in new ways. In this journal, products and the ideas behind the products were portrayed in a way that had an affinity to the way I work and the ideas behind the products - which together help to build up a kind of brand…*

Conceptual representation, nature, and technology: *The logo was designed with inspiration from the furniture tools, and an added value was that it can illustrate growth rings in a tree - a mix between the machine and the natural…*

Emotional recognition and interaction revitalise cultural heritage: *You can decide how bright you want it to shine by turning the tightening mechanism…By using an old technique as a mediating tool in a* *new and innovative way, values are added to the product which may cause the user to be more connected to it through association, and this might create a desire to keep it for a longer time. The new and the old together thus may create more long-lasting and sustainable products and, in addition, may contribute to revitalize cultural heritage.*

Business, emotional recognition: *Through larger production the product can be more accessible to people in price and show continuation of our cultural expressions. In mass production the product can still, through the associations evoked by its design, contribute to a sustainable product, if it is seen as meaningful to own… (Ohlsson, 2013)*

The lamp *Turn* came into being by showing threaded timber in a new way in a new product, and it preserves and commemorates an old craft tradition rarely used today. Some other categories that emerged in the analysis were material expressions: vegetation identity, species diversity, contact with nature, and contact with the material. *Turn* further encouraged the desire to generate memories of childhood woodwork classes and old craft traditions. The lamp encourages interaction between user and product. The user must touch the lamp to turn the light on and off. Materials are birch and mouth-blown glass. It is manufactured by the furniture company Bolia. The product has contributed to a marketing strategy of corporate social responsibility [18] for the Forest Owners' Association in their magazine *Skog* [Forest].

## 5 DISCUSSION

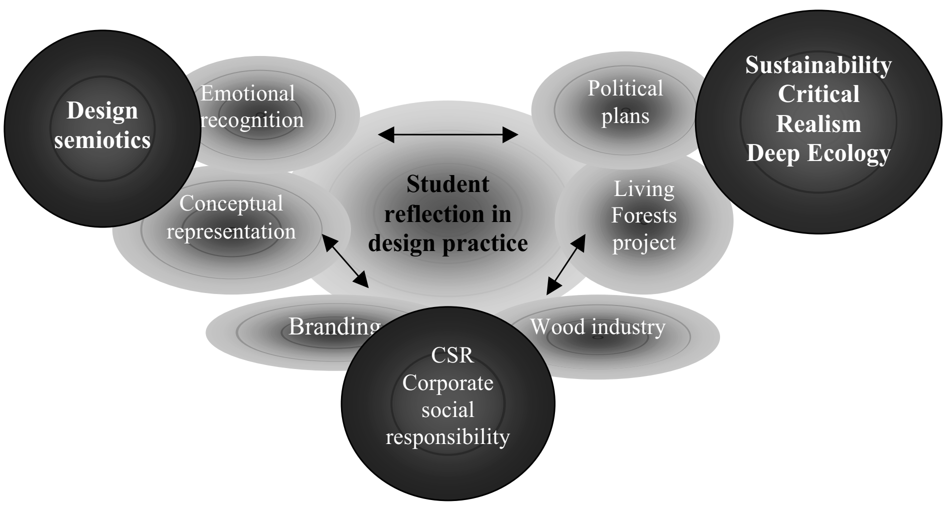


*Figure 2: A pedagogical concept for sustainable thinking in design education.*

The findings showed design qualities as described by Rune Monö [6]. Examples of such qualities are the semantic quality of the large-size screw, which due to its threaded body, obviously is made to turn. The screw could make the object look like a tool, but the additional elements of cable and frosted glass clearly tells the viewer it is a lamp. This makes it likely that turning the screw affects the light. The blown glass and the wooden parts give associations towards handicraft and quality. The feeling of quality is enhanced by the lamp's high finish. The lamp has strong cultural associations to old woodworking tools, but it still looks modern due to the combination of wood, glass and its high finish.

These design qualities are discussed in two philosophical views that bring together nature and technology in different ways: Critical realism by Roy Bhaskar and Petter Næss [9] and Deep Ecology by Arne Næss [3, 19]. In Deep Ecology the view of nature is that, one not only has to think about man's close relationship with nature, but that all animals and plants belong in a holistic perspective [3]. In Deep Ecology [19] everything is connected with everything through a mutual, dependent relationship in a long-term perspective. It is a symbiosis where all parties extract mutual benefits from each other through a true companionship. Deep Ecology emphasizes the importance of relational thinking, holistic thinking, and system thinking. These are all factors of importance within a holistic design perception. In relation to the lamp *Turn,* Deep Ecology is also interesting through its striving for preservation of diverse cultures. The lamp has a strong cultural identity and roots to cultural heritage. In such an ecological and sustainable view of the world, self-realisation means that the self is widened by seeing ourselves in others and in our environment. This leads to a deepened perception of reality and our own self; a deepened realism [20]. "*In this journal [Forest], products and the ideas behind the products were portrayed in a way that had an affinity to the way I work and the ideas behind the products",* the master student said.

In critical realism, the view of nature can be associated with how Petter Næss [9] discusses the scientific rationale that urban planning should be possible and meaningful, pointing out critical realism as a prolific science and theoretical platform for urban research. Several of today's most prevalent epistemological positions are incompatible with bringing forth the knowledge base needed for urban planning to play a meaningful role. Critical realism considers interdisciplinary integration as necessary, while competing positions, e.g. positivism and post structuralism neglect and exclude important parts of reality. Critical realism recognises both actors, and structures independent, causal, impact forces and thus provides a good platform to examine the causal relationships between social, spatial structures and actors' actions like those performed by planners. Here, the product-design, master student acts as a designer within the structure of the forestry business. Critical-realism views on what kind of research-based predictions are possible fit with the product designer's qualitative impact assessment of solution options and careful context-adapted estimates of effects of the product she designed. The design master student considered the effects of handicraft traditions, cultural heritage, branding, materials, colours, new uses for forest products, and mass production as a basis for the action of designing the lamp.

### 5.1 Conclusion – implications in design education

The conclusion of this study is that it has possible implications in design education and design practice. Our aim has been to explore how a design theory like product semiotics [15] is good but insufficient in aiming for a sustainable design process, and that it does not capture considerations like innovation in the timber and forest industries. The study indicates that product design, based on sensitivity for material origin and cultural heritage, can contribute to holistic thinking, thus connecting design, forestry, and technology. Therefore, we may need to expand design theory with ecological theory [3], perhaps critical realism [9], or both. Further studies could contribute to an understanding of which elements of their theories could be more relevant in design practice, or whether a combination of these theories might be possible. Students can thus get an expanded view on learning outcomes, on material techniques, as well as how such techniques are an integral part of a worldview.

Such a positioning of design practice requires cross-disciplinary collaboration which may contribute to an expanded view on aesthetic experiences [21] and a deepened understanding of self-realisation from an ecological perspective [20]. Experiences that expand the product itself, its use, and its form language, where product design is intertwined in a complex way with the designer's self-identification and ethical values, reflect industry, technological innovation, and social values like cultural heritage, as demonstrated in this study.

### 5.2 Learning outcomes, product materiality, and sustainable environment

The learning outcomes identified [10] in the case study are relevant issues in human technology relationships in product design that concern knowledge, skills and general competence. Knowledge is to understand that the materiality and product qualities belong to a broad-based and sustainable consumption perspective. Skills are related to how the material's inherent properties through the shape and design can give signals about the origin and culture. A general competence is to see nature and design as mutually corresponding elements in a global, sustainable perspective. This case study is associated with a single product, but the phenomena identified might be of general interest and might have transfer value to other products, architecture, and system thinking from an environmental perspective [14]. However more studies are needed to explore a sustainable integration of possible connections between nature, culture and technology, and how it can be transferred into new arenas. Such arenas could possibly be found in the creative industries, the forestry and wood industry, or service-design in the field of primary industry.

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# OPEN DESIGN AS AN EDUCATIONAL TOOL IN ARCHITECTURAL STUDIES

**Alexandros Theocharis VAZAKAS**
Lecturer, School of Architectural Engineering, Technical University of Crete

**ABSTRACT**
The paper presents a course that introduces Architecture students to product design, materials, techniques and fabrication processes. The course uses a combination of digital fabrication tools and parametric design software – a combination often cited as "Open design". It also uses a rapid prototyping laboratory which among other things facilitates the transition from design to the actual product. Designing a chair is under a certain perspective no different than designing a building. There is a different context, different constraints but both are essentially design processes involving craft, geometry, materiality, function, structure and fabrication. The fusion between the disciplines of Architecture and Product Design attempted in this 4th year course focuses in a way of making architecture where the process of construction is as important as the form itself. A paradox is then created: by using the most advanced technological tools, the act of building is conceptually closer to its primitive form. The architect is also a craftsman, able to shape matter with his own tools. The paper presents the core theory behind the course and the results during its 4 year long history within the curriculum of an Architecture School.

*Keywords: Digital Fabrication, Craft, Open Design, Associative Design*

## 1 INTRODUCTION

Three reasons lead to the insertion of Product design into this architecture course:

- Scale: The design of easier to build artefacts creates a "shortcut" for the students. An opportunity to use a feedback loop, informing building design with material, process, and formal data.
- Friction with Fabrication: Construction processes, the notion of economy within construction contribute to the understanding of building construction as a process
- Functionality and structural stiffness: products (like buildings) have an even stronger need for a specific function and a structural integrity with respect to the construction process implemented.

The use of a rapid prototyping lab, especially one that fits within the norms of a fablab,[1] serves a triple purpose: Firstly, it greatly enhances the construction capacity in terms of speed and accuracy, secondly the fablab setup allows the implementation of almost any construction technique and thirdly the computer associated manufacturing allows for an "open design" approach.

Seen under a broader perspective, the course puts forward several critical issues: the relation between geometry, construction techniques and alternative ways of conceiving space, the issue of using invariants and variables in Architectural design, and finally the seamless integration of information technologies into the architectural profession.

There seems to be a bidirectional relation between geometry and construction techniques: on the one hand man is trying to impose abstract geometrical forms on matter, and on the other, material processing techniques seem to give birth to geometrical concepts. (e.g. ceramics and revolved

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[1] Fablab: A fablab is generally equipped with an array of flexible computer controlled tools that cover several different length scales and various materials, with the aim to make "almost anything". This includes technology-enabled products generally perceived as limited to mass production.
While fablabs have yet to compete with mass production and its associated economies of scale in fabricating widely distributed products, they have already shown the potential to empower individuals to create smart devices for themselves. These devices can be tailored to local or personal needs in ways that are not practical or economical using mass production. [2]

surfaces, textile weaving and matrix etc). Geometry itself presents a structure that consists of invariants. Mathematician Felix Klein in 1872 [1], proposed a taxonomy of geometrical theories in successive layers, defining geometry as the study of those properties of space that remain constant under the influence of a specific group of variations. Under this perspective, and while the only things that differ between Klein's layers are these invariants, one can notice a continuity between different geometries. Every "layer" expresses a different way of conceiving space. Within the discipline of Architecture, B. Cache links these layers with the techniques on which, according to G. Semper Architecture is founded.

Felix Klein's theory on the layers of Geometry can be expanded to Architecture: We can view each building as a Geometrical theorem which is structured on relations that remain invariant and allow for a certain width of variations. This leads us to the conception of the architectural artefact not as a single object but as a series. On top of that, with the aid of the proper digital tools, design of space can become collaborative and interactive.

The connection of Architecture to the technical professions which for Semper is critical, has been expressed after the industrial revolution with the Arts & Crafts movement and consequently with the Bauhaus school. There, it has also been linked with the contemporary technology of the time. Today information technologies having dynamically invaded all the layers of industrial production are continuously altering this relation of construction with technology. This relation constitutes by itself a field for research.

All of the above mentioned issues are put forward in the course "Associative Design" of the Department of Architecture at the Technical University of Crete. In order to present the structure of the course and the results thus far, it is necessary to refer to the relation of Geometry and Architecture under the theories of Felix Klein and Gottfried Semper, the concepts of variants and invariants as they appear in the works of Bernard Cache, and in those CAD/CAM technologies that contribute to a new vision of industrial and building production.

## 2 GEOMETRY, CONSTRUCTION, ARCHITECTURE

In 1872 as a professor of Mathematics in Erlangen University, Felix Klein formulates the first general overview of Geometry since 300 bc when Euclid composed his "Elements" [3]. The principal directions of the research thus far could be summarized to the study of variations related to non metric properties (projective geometry) and the questioning of Euclid's fifth postulate that lead to less defined and more "flexible" geometries. It is by basing his research on these directions, that Klein defined Geometry as the study of those properties of space that remain constant under the influence of a specific group of variations. As a result, Geometry is presented as a multi layered edifice, with every layer characterized by invariant properties. The four main layers of that edifice, those of the greater historic significance are Isometry, Similitude, Projection and Topology. Isometry, which deals mainly with distances and angles, is the geometry that studies properties left unchanged during translation and rotation. Similitude that alters length but keeps the angles and the proportions of lengths invariable consists for Klein a separate Geometry that together with isometry define Euclidean Geometry. Projective Geometry studies the properties of objects left unchanged during projection, meaning – between others- the bi-ratio of lengths, intersection and alignment. Topology studies the properties left invariant during topological transformations, namely stretching and distortion. [4]. Through Klein's reordering of Geometry one can distinguish the very nature of science which is the creation of more sophisticated invariants that allow for even more variations. These four geometries represent different ways of thinking about space and therefore different procedures in Architecture. Bernard Cache connects these geometries with the four fundamental techniques according to Semper: Ceramics, Tectonics, Stereotomy and Textile[2]. [3], [5]. According to this view each one of these techniques refers to primitive models that correspond to the basic transformations which characterize the Geometries recognized by Felix Klein. Ceramics refers mainly to revolved surfaces coming from the technique of the lathe. Tectonics cannot be separated from the problem of proportion. Stereotomy was the field of application of projective geometry and finally the founding pattern of textiles – the knot- is one of the most complex topological entities. Consequently, different geometries impose powerful

[2] In Semper's own words: " It will be shown that the fundamental principles of style in the technical arts are identical with those governing architecture, that the simplest and clearest expressions of these principles are to be found in the technical arts where they were first established and developed." [6]

restrictions in the ways we conceive, behave and act into space and have already defined Architecture from its very beginning although their theoretical foundation was yet to be structured.

## 3 VARIANT AND INVARIANT, ASSOCIATIVE DESIGN

Thanks to software such as Rhino or Maya, it is very easy to build and edit complex surfaces topologically by moving control points. This kind of processing though, is abstract and is not combined with structural and material parameters. Such a process refers more to the model of the Architect – Artist and to non standard but also very expensive structures. Based on the theme of "invariant by variation" that he discovers in Geometry, and on the close relation that the Architect should develop with the means he has in his disposition, Bernard Cache supports an Architecture that can be economical, constructible and consequently addressed to everyone. Nowadays writing code is one of the most important products of contemporary civilization but also the field of collision of the forces that define production. Within this framework the concept of associativity is already playing a decisive role in "standard" architectural production. The term associativity refers to software that allows composing an architectural project based on a long chain of interdependent relations, from its conception to the code that drives the machines that will fabricate the various connecting parts. Designing with associative software mainly means to transform a geometrical drawing to an interface of a programming language. Through associative design it is possible to control complex aggregations of different elements that we cannot draw one by one. This fact requires the process of insertion of components. In this case, the general model (assembly) is in a way an invariant able to support all the variations.

## 4 CONSTRUCTION TECHNIQUES AND DIGITAL TECHNOLOGIES

In the non standard Architecture envisioned by Bernard Cache, there should exist, prior to the constructed edifice, an abstract architecture, one that manages the flow of information with such efficiency that there are no intermediates between the designer and the machines. [7]. Nowadays, research has progressed and these technologies are becoming more and more accessible financially. The change related to the architectural product is taking place silently and follows the industries and market terms. CNC construction technologies can be divided into three broad, process based categories: machining or material removal processes; deformation, moulding and casting processes and fabrication or additive processes [8]. The Digital Fabrication laboratory in the Department of Architecture at the Technical University of Crete has been created in order to address most of the above mentioned categories. The Laboratory is fully functional since the academic year 2010-11. It is equipped with laser cutters a 3 axis cnc router and a 3d printer. It is addressed to students, teaching staff and anyone who wants to make something out of a digital file. In Architectural education, the close relation to the applied arts was founded at the Bauhaus School. Its program was among others, founded on Taut's belief that "There are no boundaries between handicrafts and sculpture or painting; they are all one: building."[9] The establishment of such a relationship within architectural education, besides the obvious fact of familiarizing students with materials and techniques, is building much stronger bonds with geometry, bonds that could be related to the roots of Architecture.

## 5 COURSE'S PRESENTATION. GOALS AND RESULTS

The course "Associative design" attempts to put forward all the above mentioned issues and to function in different educational levels. Firstly, on the level of familiarization with construction techniques, traditional and new, with the 1:1 scale, materiality and the experience of construction in general. Secondly, on the level of geometry and associativity, which is an exceptional tool for a student to structure his concept geometrically and follow design paths that he could not have been found otherwise. Finally, on the level of constructability that concerns series of objects but also the rules and terms of industrial production. The course, addressed to students of 4$^{th}$ and 5$^{th}$ year is developed around the following axes:

- Projects should follow a "Vertical" approach: from design to fabrication. The forms developed should be able to be fully elaborated within the Laboratory. In this way students experience designing and building a small project from start to finish. They gain valuable experience from the friction with real parameters such as the materials used and the need for structural coherence.
- Projects should use associativity as a means to handle complex geometries both conceptually and

students get familiar with the logic of programming, with creating relations between forms and learn to hierarchically structure their projects.

- Projects should make extensive use of physical models created both manually but also with digital tools. These should reach even 1:1 scale in order to test both aesthetic and structural qualities.

During its four year long history, the course gradually focused on furniture design in the first semester and a building component design in the second. Every year a different material is chosen along with the specific techniques involved, and an attempt is made to "digitize" the material's traditional techniques in the lab.
The design task given for the academic year 2010-11 was to design a canopy out of plywood. This canopy should have a minimal use (e.g. define a space for 2 or more people), be associatively designed with no particular regard on the reasons of this associativity's initial parameters (could be sun path, topography or just a set of curves), be constructed at the school's Digital Fabrication Laboratory and use solely wooden detailing with no other material involved. For this last parameter, we used the research of Prof. .E. Burdek and J. Gros at the Hochschule fur Gestaltung Offenbach on the digital construction of wooden joints, as a basis for our detailing. Each team of students had to present a fully associative digital model, a physical model in 1:6, full scale physical models of the joints used the design process, plans, and the like.
At first, all teams experimented with sketches and small physical models. At the same time, they started elaborating the joints they would use and created wooden physical models of those.
In the student project of Figure 1, a set of curves defines a surface of double curvature. This is then constructed out of a "waffle" system of intersecting plywood beams and two ribs that form the transition to the ground. A set of triangles is placed between the openings providing shadow where needed and at the same time stiffen the structure in both directions.

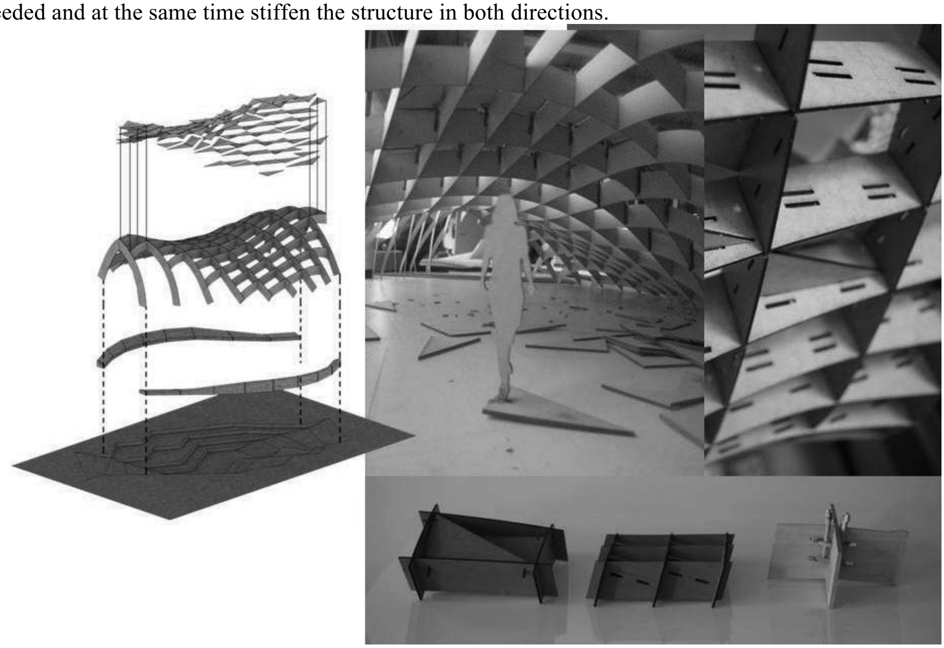

*Figure 1. Student project year 2010-11, paper and wood models (N. Assimakis,M.Messaritis,S.Vlachiotis,G.Liakou, M.Giannadakis,E.Lionaki)*

The academic year 2011-12 the design of a parametric plywood chair was chosen as a theme. Two examples are shown in Figure 2, one made out of press fit plywood panels and the other out of steam bent cnc cut plywood display the focus on the variability of the techniques.

*Figure 2. Student projects year 2010-11, prototypes from press fit and steam bent plywood (E.Chronopoulou, G.Gratsou, E.Aslanidou / A.Andredakis, S.Konstandinidis, D.Tzagarakis)*

For the year 2012-13, we used composite aluminium panels for the students' designs. Mainly the techniques of folding and rolling were implemented, as shown in the two following examples of chairs.

*Figure 3. Student project year 2012-13, prototypes, folded and curved composite aluminium panels (X.Tzatha, E.Alexiou, N.Anthouli, A.Chatzimichali / S.Ntzoufras, E.Stathopoulou, M.Teliou)*

The same year, a summer semester was introduced, where a shading device out of composite aluminium panels was developed. Various simulation software tools were combined with a parametric software in order to test and optimize the device's performance. Figure 4, shows the prototype in full scale that was constructed and put into place.

*Figure 3. Student project year 2012-13, shading device from composite aluminium panels (S.Ntzoufras, G.Prosoparis,C. Freitas)*

This year, for the winter semester the material used was fibre reinforced plastics. That decision led to fluid, double curvature forms for chairs, and a tedious process of making wooden and fibreglass moulds, in order to get to a prototype.

## 6 CONCLUSIONS

A fundamental relation between architecture, crafts and geometry is recognized, a relation which through the concepts of invariant and variation leads to a way of thinking based on continuity. Beyond the theoretical infinity of constructional and design capabilities provided by digital technologies, which very often lead to a designer's "easiness" there is a need for a deeper and more substantial connection of Architecture with man and society. A new paradigm of construction and design of space is required, a new relation between geometry and fabrication where digital technologies will be the leading factor, reuniting the human body with the almost forgotten language of construction.

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# EVALUATING LEARNING OUTCOMES OF SOFT SKILLS IN MECHANICAL ENGINEERING EDUCATION

**Jan BREITSCHUH[1], Annica HELMICH[2], Albert ALBERS[1] and Gerd GIDION[2]**
[1]Karlsruhe Institute of Technology (KIT), IPEK – Institute of Product Engineering
[2]Karlsruhe Institute of Technology (KIT), Centre for Open and Distance Learning

**ABSTRACT**
Soft skills, such as creativity, teamwork abilities and strength of implementation are essential key competencies for successful product development engineers. Within the structure of an engineer's academic education, design projects are applied as a medium to help develop professional, methodological and social competencies. At the Karlsruhe Institute of Technology (KIT) yearly events for undergraduate students (third and fourth semester) of mechanical engineering are organized, during which several hundred students are grouped into small project teams and work together to solve a common design task. During this design project, the students' progress in competence development is monitored in a total of six project milestones, the so-called workshops. In order to provide specific and purposeful feedback on the status quo of competency development, a five-dimensional competence model is used. The five dimensions are professional competence, methodological competence, creativity, teamwork abilities and strength of implementation. In this work a federal funded project with the aim of evaluating learning outcomes especially of soft skills in a reliable and valid manner is presented. Since the past two years of the research project several empirical investigations were made and led to specific tools which are currently under testing in the workshops. As a next step, these individual measures are to be integrated and enhanced in an Intervention Toolbox which is supposed to provide teaching personnel a set of instructions to create, analyze and interpret situations where students must show their soft skills.

*Keywords: Project-Based Learning, Intervention Toolbox, Soft Skills Evaluation, Assessment*

## 1 INTRODUCTION

Engineering education at universities is undergoing extensive changes towards teaching skills and competencies more than sheer knowledge. In order to develop suitable teaching models a proceeding investigation on mechanisms of competence-building is necessary. Having performed case-based education of engineering design students at the IPEK – Institute of Product Engineering over a long time, current trends like competence-oriented teaching are regarded as opportunities to investigate the basis why case-based education performs so well [1, 2].

In Germany, teaching engineering has always had a systematic relation to science as well as an equally important practical relevance. Both paths place a high demand on teaching strategies and learning outcomes. On the specialized scientific side, the subject matter is growing more demanding and requires more effective cognitive strategies. Whereas on the practical side, the challenges involve more methodological, social, collaborative and creative competencies [3, 4]. Therefore, the scientific field is due to assimilate a more operational and professional practice. One way to connect the two fields is to bring the engineering work into the education at a tertiary level.

## 2 KARLSRUHE EDUCATION MODEL FOR PRODUCT ENGINEERING

Since 1996 students of mechanical engineering at the IPEK – Institute of Product Development at the Karlsruhe Institute of Technology (KIT) undergo the KaLeP – Karlsruhe Education Model of Product Engineering [1]. The KaLeP is an integrated system for teaching product engineering skills. It consists of six basic elements, which form the core of each of the IPEK's courses (Figure 1).

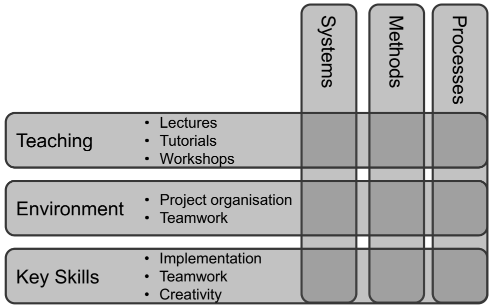


*Figure 1. Integration Aspects*

The three elements systems, methods and processes characterize different levels of detail in product development (Figure 1, on the left). Systems in this case means specific technical systems such as clutches, gearboxes or entire vehicles. Basic knowledge of technical systems is gained by the students mainly in lectures. A first step towards applying the knowledge to technical problems is made in tutorials. In order to develop competencies in product development, the students participate in an accompanying product development project. The development task is characterized by a certain complexity and uncertainty concerning the completeness of the task description. By applying methods of product development to their project task, the students learn how to systematically cope with these demands, develop creativity skills and improve their tolerance of frustration. Another very important aspect of the KaLeP is its focus on providing a realistic learning environment. Being organized in teams of five the students face certain difficulties when organizing their development project, defining work packages and preparing project milestones. Therefore the process aspect of product development as a sequence of problem solving activities in a team can be experienced by the students. Especially in the project milestones, the so called workshops, the development of key skills such as strength of implementation and teamwork competencies is fostered by giving specific feedback about the current level of competency development to the students. In the following the main focus will thus be laid on the undergraduate product development project work and the corresponding project workshops. Figure 2 shows such a workshop situation.

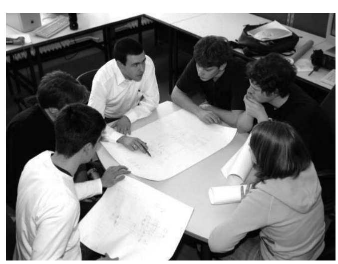

*Figure 2. Workshop Situation with tutor and students*

During the third and fourth semester the undergraduate students of mechanical engineering participate in a total of six workshops, each with a duration of four hours. During these workshops the milestone tasks and work packages are assessed and a feedback on the students' individual performance as well as the team performance are given.

The rating system with which this feedback is structured consists of five rating dimensions rated on an ordinal scale: professional competence, methodological competence, creativity, strength of implementation and the ability to work in a team (Figure 3). These dimensions allow an overall rating of competence profiles and are adapted to the specific learning arrangement from various sources [4, 5, 6, 7] and industry experiences [1, 3].

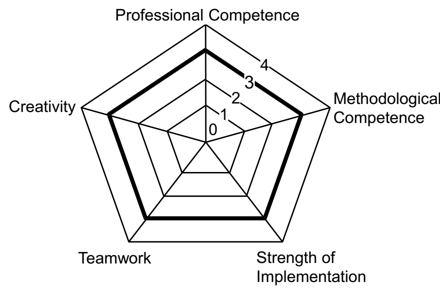


*Figure 3. Five-Dimension Competence Model*

In order to rate the students' state of competence development as reliable as possible, a corresponding description of the five dimensions was designed on the basis of empirical research data (table 1).

*Table 1. Skill Sets and possible Interventions*

| **Competence Dimension (weight)** | **Indicators** |
|---|---|
| Professional Competence (5) | • Precise and correct answers to questions concerning lecture contents<br>• Create neat technical drawings conforming to standards (Function, Form, Sealing-, Lubrication- and Mounting-concept)<br>• Correct use of technical terms and proper technical design of models |
| Methodological Competence (5) | • Professional use of CAD<br>o Structure of model, reasonable use of tools, no global interference<br>• Organization and record keeping of project planning<br>o Work packages, milestones, Gantt-Diagram<br>• Decision making process needs to be documented<br>o List of criteria, protocols of discussions, value-benefit-analysis<br>• Supporting tools/software used in reasonable manner<br>o e. g. Maple, FEM, Blender, MS Visio, etc.<br>• Taking into account and illustrating the properties of the entire system<br>o Production and maintenance costs, weight, etc. |
| Creativity (2) | • Generating unconventional solutions (comp. progress of the lecture)<br>o Quality of ideas: general functioning and suitability to the problem<br>• Ability to create a variety of ideas<br>o Quantity of ideas: variety |
| Teamwork (2) | • Collaborative working inside and outside the project meetings<br>o Project and resource planning, distribution of tasks, meetings<br>• Clear communication within but also outside the team<br>• Transparent depiction of procedures within the team and ability to perform as a team<br>o Agreements, positions and tasks, organization of the group's work |
| Strength of Implementation (2) | • Presentation of ideas and solutions as a group towards others<br>o Selling" of one´s ideas<br>• Defending of one´s conceptions against other views and criticism<br>o Objective arguing, adapting criticism in a constructive way<br>• Brief depiction of localization of problems and selection of solutions<br>o Procedure in making a decision (Advantages, Disadvantages) |

Note that not all dimensions are weighted equally which is due to the focus on professional and methodological competences in basic engineering education. These key competencies go into the evaluation with the factor five whereas the other count in twice. Another important aspect is, that the dimensions are overlapping in some facets (e. g. project planning as facet of methodological competence and distribution of tasks as a facet of teamwork). The difference is in the main dimension to which the facets are assigned. In the given example this means, that regarding teamwork abilities the students should commit to a balanced workload planning where no team member has to work more than another. Regarding the Methodological competence dimension the committed project plan should be documented in an appropriate way in order to explain project progress, work packages and project structure to a third party. This overlapping requires the teaching staff to be trained to apply the competence model.

On the other hand this model allows to provide direct and specific feedback on the level of the students' competency acquisition and to give recommendations for suitable improvement actions (e. g. teambuilding, creativity techniques or steadfastness in the workshops) and thus enables the learners to continuously evolve their competence profile. In the end, the students become capable of developing complex products on the basis of requirement specifications. The race scooter in figure 4 is an example of a student team's project result from 2012.

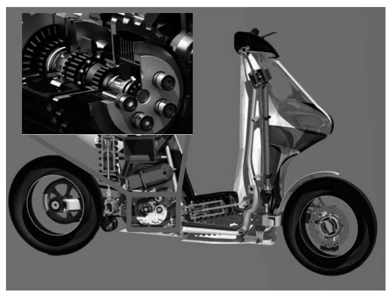

*Figure 4. Student's Project Result – Race Scooter*

## 3 SPECIFIC RESEARCH FOCUS

For many years, concepts of project work and learning, such as the KaLeP, have been implemented in university studies in engineering. Project topics and project work are orientated towards the engineering activity of professional practice and integrate into the university's technical theory curricula [8]. The complexity of the individual project tasks ensures students apply systematic and structured methods in order to solve the problems at hand. However, tasks within the engineering field are not comparable to mathematical problems, where the solution is either right or wrong, as product development tasks have various possible solutions. The difficulties lie on one hand within the evaluation of the learning outcomes for the different solutions, and on the other, the several interdisciplinary skills which the students achieve. Plus the competence model's facets have to be assessed in a rather strict way in order to avoid rating bias as mentioned above. So despite of having proven its worth, there is a need for empirical tools specifically matching the competence model and the learning arrangement in order to rate the students equally. The aim of this study is to develop empirically based interventions, so that the student tutors and scientific supervisors are able to validly assess the learning development process. For the successful evaluation of soft skills, there are several requirements: The tutors and supervisors need to know, understand and accept the educational objectives of the soft skills. They also need to master the didactical interventions and should have certainty in dealing with the indicators of the competencies, with which they provide feedback to the supervised student teams and initiate competence development.

As mentioned above, the competence development is monitored and with evaluation criteria and a corresponding form sheet. On this form, each of the five dimensions of the competence model is assessed. We will however focus on the final three aforementioned "soft" skills, which are difficult to assess practically [9]. Therefore, there is a need to develop an empirically based didactical interventions in order to have a reliable assessment tool.

## 4 RESEARCH METHOD – THE INTERVENTION TOOLBOX

The first step to develop such an assessment tool would be to investigate how the practice of assessment has taken place up until now. Thirty-nine observational sessions took place and were carried out by various student teams. They observed the specific workshop situations and the private working meetings of the students. An additional six scientific supervisors were interviewed during this process. Through this practical view on product design education at tertiary, a competence development guideline was created (table 1). This includes systematic indicators, with which the tutors and the scientific supervisors are able to assess the students. This guideline is specifically used for the teaching practices at the Institute of Product Development. The guide is short, no longer than one page, but still needs to address every dimension for each of the competencies. In further work, the individual dimensions will be literary founded to a greater extent and elaborated in more detail. For every partial-dimension, there will be one to three short interventions developed for the practical project work.

For the interdisciplinary competence dimensions, observable examples need to be found. This means, the tutor rates the performance of the students and not their competence. For team work, this area should be broken down individually. The observed skill groups are based on literature written by Geis [10]. This area has been analyzed in his writings "Behavioural Markers in Product Development Success and Power Factors in Team Effectivity". He names the following aspects as part of successful teamwork:

- Communicative strategies such as feedback and active listening
- Strategies for conflict management
- Situation analysis and assessment
- Process planning and execution
- Reflection

Supplementary to these aspects named by Geis, the point "capture multiple perspectives" should also be added. This means that knowledge should be flexibly transferred to other problematic situations. This can be seen as one of the most important skills an engineer may possess. The corresponding interventions are required to be short time-wise, so that they can easily be integrated into the four-hour block event. Furthermore, the interventions should not require a long familiarization phase; the tutor and the scientific supervisor should be able to apply the methods immediately. The following will introduce examples of the most plausible interventions for team work (table 2). For a better understanding, a few interventions methods are detailed below.

*Table 2. Skill Sets and possible Interventions*

| **Skill Set** [10] | **Possible Intervention [11, 12, 13]** |
|---|---|
| Communicative strategies (Feedback and active listening) | Organized Feedback, SIL |
| Strategies for conflict management | Advocate Method, Muddiest Point, Pro-Contra Argumentation |
| Situation analysis and assessment | Metaplan technique, Active structuration |
| Process planning and execution (milestones) | Project planning, Project oriented learning |
| Reflection | Questioning technique, Flashlight |
| Multiple perspectives (flexibly transfer knowledge to other problematic situations) | Headstand method, Six Thinking Hats [14] |

Interexchange and active listening can be stimulated via the SIL (translated as Systematic Integration of Solution Elements). For this process, each team member compiles their own approach to solving a problem individually. Their suggestions are in turn presented and a high quality combined solution is built by the team as a whole using the benefits found within the individual ideas. The Advocate Method prepares students for possible conflicts later in their everyday working life and also helps to assert their own ideas through direct opposition. The Tutor or one of the group members takes the position of the “advocate”. He gives arguments in which the group does not agree with. So the others are engaged in an argumentative discussion process. With Muddiest Point, every group member is required to name the task aspects which appeared to be the most difficult or confusing. In a Muddiest Point exercise, students are asked to report what idea, topic, etc. about the previous workshop was confusing or unclear. The tutors and scientific supervisors collect all “Muddiest Point” responses and later read and analyze them to see what areas of the lesson or assignments students are unclear about. Students learn to articulate difficult topics and the faculty members get a direct feedback for their work. The headstand method is based on the reversal of the original problem. The students leave their customary thought patterns, and are then in the position to methodically transfer their knowledge to other problematic situations.

## 5 CONCLUSION AND OUTLOOK

In retrospect, evaluating the learning outcomes of soft skills in mechanical engineering education can be achieved with the right amount of structure, guidance and direction. In regard to teamwork, a literary analysis supplement should be created for the partial skills highlighting the respective measures required to evaluate creativity and strength of implementation. Interventions should be made available to the tutors and the scientific supervisors in a structured and manageable form as an intervention toolbox. This toolbox contains guiding information about in which phase of the project work the interventions should be applied. For example, at the beginning of the brainstorming session or rather at the end before the final presentation. Furthermore, there is a precise schedule with guiding tips which directs the observation of the competence dimensions. Through all of these steps, the tutors not only ensure that the competencies are more visible, therefore being easier to rate, but are also able to specifically target the development of these skills.

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# A CASE STUDY ON THE DESIGN OF A MODULAR SURGICAL INSTRUMENT FOR REMOVING METASTASES USING ENGINEERING DESIGN TOOLS

**George PRECA[1], Philip FARRUGIA[1] and Aaron CASHA[2]**
[1]Concurrent Engineering Research Unit, Faculty of Engineering, University of Malta
[2]Department of Anatomy, Faculty of Medicine & Surgery, University of Malta

**ABSTRACT**
Metastatic cancer is a form of cancer stemming from a primary tumour that propagates to different organs and/or to different sites within the same organ [1]. Studies have indicated that the chances of survival improve upon surgical removal of metastases [2]. The overall goal of this research was to develop a modular surgical instrument that would be easy to use and manipulate and hence facilitate resection of metastases. This research forms part of a final year project carried out by a mechanical engineering student in the four-year bachelors course at the University of Malta. The basic design cycle [3] taught in the third year of the course was employed to systematically generate the design of a novel modular surgical instrument. This was complemented by a number of hospital visits and various meetings with professionals and other stakeholders relevant to the field. Through this case-study, this paper shows how, even at a bachelors level project, the application of design tools and the continuous communication with typical end-users can lead to the development of a high-value added product which can be potentially commercialised. Other benefits of joint supervision are also discussed.

*Keywords: Basic design cycle, learn-by-doing, design iterations*

## 1 BACKGROUND

Almost 90% of cancer deaths are due to metastases, making this a very dire problem [2]. Even when the primary tumour has been completely removed, there is no guarantee that the patient is in the clear, as the cancer may have already spread [1]. The excision of metastases can be challenging, hence there is a clear need for a novel surgical instrument to facilitate excision [4].
Lung parenchyma is the second most frequent site for metastases with 30%-50% of all cancer patients developing lung metastases. This led to the project being focused on lung metastases [5]. Currently, a pulmonary metasectomy is a procedure that can be performed multiple times as long as conservative resections are made [6]. Older instruments and techniques often led to patients with multiple metastases being labelled incurable due to extensive damage to the lung parenchyma [6]. Nowadays more novel state-of-the-art instruments have led to patients previously thought to be incurable being offered a cure [6]. Yet, a critical literature review of the state-of-the-art of surgical instruments revealed that such instruments do not satisfy all the attributes required by surgeons, in particular ergonomics, reusability, the ability to facilitate minimal invasive procedures and the capability of addressing metastases of varying size.

### 1.1 Introduction to the project

To this end, the overall goal of the research disclosed in this paper concerns the development of a modular surgical instrument for removing metastases. To systematically accomplish this goal, the basic design cycle BDC [3] was employed. A number of engineering design tools were employed in the different activities of the basic design cycle. This design methodology is commonly taught in various engineering design curricula, including the curriculum at the University of Malta, as described in [12]. The work was conducted by a mechanical engineering student in the fourth year of the bachelors course. This student had previous design experience during the third year of the course. As described in [12], during the fifth semester, students are taught the design methodology and the various tools available during the BDC activities. In the sixth semester, they are given a group project during which they have the opportunity to apply these tools to design an innovative product. This project was a result of internal collaboration between the Concurrent Engineering Research Unit within the Department of Industrial & Manufacturing Engineering, Faculty of Engineering and the Department of Anatomy, Faculty of Medicine and Surgery at the University of Malta. As a result was supervised by one academic from each of the aforementioned departments. This enabled the student to get feedback on the evolving solution from an engineering design point of view and also from typical end-users' perspective through several meetings with local leading surgeons.

The structure of the rest of the paper follows the basic design cycle, covering the problem analysis, synthesis, solution analysis and evaluation (Sections 2 to 5). Conclusions and reflections are drawn up in Section 6.

## 2 PROBLEM ANALYSIS

The workflow of a surgical procedure is constituted of three main steps, namely incision into the patient, removal of metastases and sealing of tissues. This paper focuses on the second step. In addition as a research boundary, it was decided that the surgical instrument should facilitate open approach surgery, thus allowing digital palpitation of the lungs, as 65% of surgeons felt that this was essential in ensuring that all metastases were removed [7]. A clay model of the lung was constructed leading to a greater level of understanding of how metastases appeared in the lungs.

### 2.1 Communication with end-users through visits and surveys

A number of meetings were held with surgeons at the main hospital in Malta. The most crucial conclusions drawn from these meetings were that, firstly, metastases varied in size from 0.5-3cm and, secondly, they are usually perfectly spherical in shape and should be removed in one piece. A survey was also carried out with surgeons in order to understand their expectations from this surgical instrument. Results reveal that surgeons gave priority to their ability to operate the instrument with one hand, to good ergonomics and to having a rigid, robust product. The survey also highlighted the fact that the mode of operation of the instrument and the maintenance required were important and so a simple, easily assembled design provided the best solution. On the other hand having good aesthetics and no external power supply were aspects not valued very highly. A *quality function deployment* (QFD) exercise was also conducted with surgeons, from which it resulted that the most important technical parameters were mode of operation, cost, suitable choice of materials, size, weight and ergonomics of the instrument. A Product Design Specification was also drawn, in which the criteria on which to base the concepts in solution synthesis, were documented.

## 3 SOLUTION SYNTHESIS

The function of the instrument was disassembled into a number of sub-functions. Brainstorming and sketching were extensively used, giving rise to a number of working principles.

### 3.1 Morphological Chart

A morphological chart was drawn up as shown in Figure 1. Amongst the different means for each sub-function, seven potential paths were identified. These solutions were screened in order to find the solution that best embodied the design requirements; this was principle solution 1 that is characterised by a black line in Figure 1. The means (if any) selected for each sub-function are shown in Table 1.

## 4 SOLUTION ANALYSIS

Weak spots of the selected principle solution from the morphological chart were analyzed using a value analysis profile, as shown in Figure 2. The numbers 1-10 are the grading parameters in the evaluation chart, which are also listed in Figure 2. The principal solution selected was rated weak with regards to parameters 8 and 9. However, medical professionals did not consider these sub-functions as important to the final design. In addition, the parameter 'performs multiple tasks' (such as the ability of the instrument to coagulate and divide tissue) was not considered at all important by relevant stakeholders.

## 4.1 Physical Modelling to Test Ergonomics

Based on the selected principle solution, three clay models were fabricated, having different configurations as shown in Figure 3a. These physical models were evaluated with medical professionals. This exercise was aimed primarily at addressing *Design for Ergonomics*. Demanding long surgeries make an ergonomic instrument design essential, as poor ergonomics causes a decrease in productivity and an increase in the number of operator errors [8]. Following the feedback received and in reference to anthromorphic data, a new clay model (see Figure 3b) was fabricated. After consulting with medical staff, it resulted that the new configuration was more ergonomic. Other *DFX* tools were employed in order to further improve the evolving design solution.

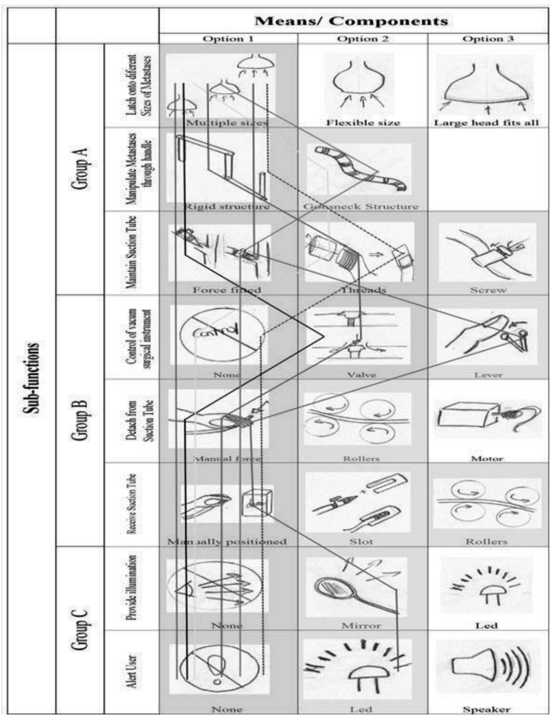
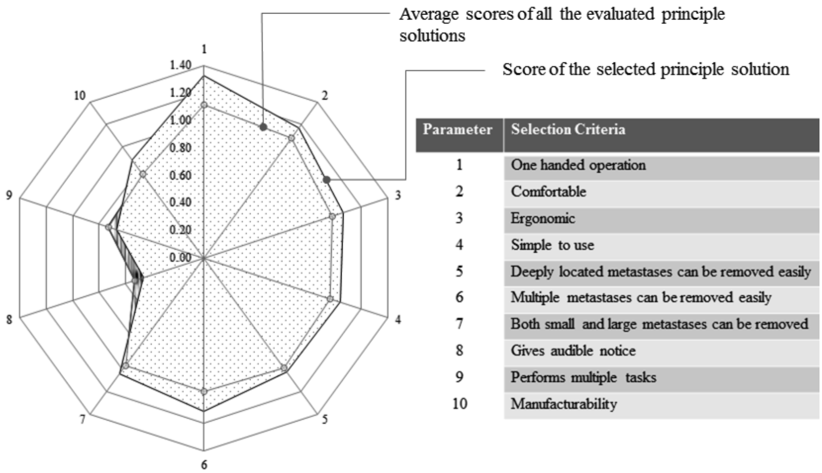



Figure 1. Morphological Chart

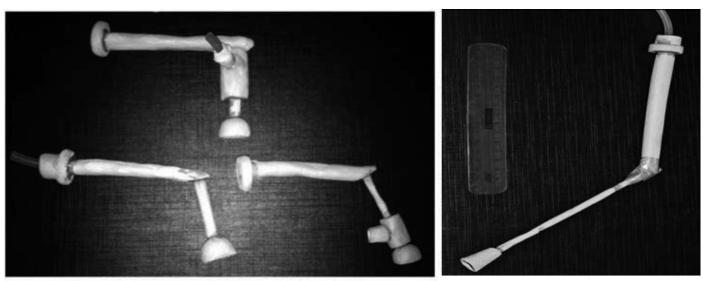
*Table 1. Means for relevant sub-functions*

| Sub-Functions | Mean |
|---|---|
| Latches onto different sizes of metastases. | Multiple suction heads |
| Manipulates metastases through the handle | Rigid structure |
| Maintains the suction tube | Force fitted |
| The vacuum is controlled through the surgical instrument | Valve [user's finger] |
| Detaches from the suction tube. | Manually positioned |
| Receives the suction tube | Manually positioned |
| Provides illumination | None. |
| Alerts user | None. |




| Parameter | Selection Criteria |
|---|---|
| 1 | One handed operation |
| 2 | Comfortable |
| 3 | Ergonomic |
| 4 | Simple to use |
| 5 | Deeply located metastases can be removed easily |
| 6 | Multiple metastases can be removed easily |
| 7 | Both small and large metastases can be removed |
| 8 | Gives audible notice |
| 9 | Performs multiple tasks |
| 10 | Manufacturability |

*Figure 2. Value analysis profile of selected principle solution*



(a) (b)

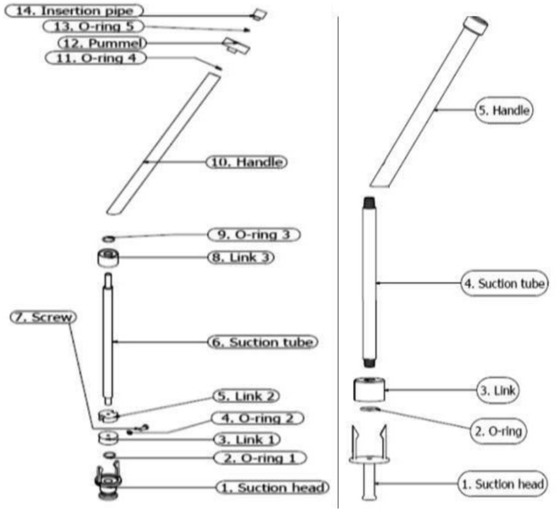
*Figure 3. Clay models of (a) preliminary (b) final device configuration*

## 4.2 DFX

Since the product would be re-usable and would be sterilized repeatedly, it was essential that the sterilization process be kept as simple as possible. Thus guidelines from the U.S *Food and Drug Administration* (FDA) were adhered to by avoiding valves regulating flow and by designing a device could be disassembled [9].

Through rigorous re-design following *Design for Assembly* (DFA) principles, a significant improvement of the instrument was achieved. The initial and final designs are illustrated respectively in Figures 4(a) and 4(b). Moreover, *Boothroyd and Dewhurst* tables [10] were used to quantify the DFA results achieved as shown in Table 2.

It must be noted that a library of biocompatible materials capable of undergoing sterilization procedures was compiled, and then using material indices, the materials for all 5 components illustrated in Figure 4b were selected. To manufacture the device, two fabrication processes are required – injection moulding of the suction head (including cup and snap fits), plastic processing utilizing *APEC 1745* resin and machining processes to fabricate the link, suction tube and handle utilizing *Stainless Steel 316L*. The suction tube assembly was analyzed in detail through the use of tables found in [11]; resulting in a 20.7% savings in the total cost of machining. Through the use of *Moldflow* simulation software and general injection moulding guidelines, the suction heads achieved 100% fill-ability as shown in Figure 5a. It must also be mentioned that detailed calculations were carried out to establish the forces acting on the snap fits and the dimensions of the suction cups.




(a) (b)

*Figure 4. Number of parts (a) before (b) after DFA exercise*

*Table 2. Quantified DFA results [10]*

| | Initial design | Final Design | % Change Improvement |
|---|---|---|---|
| No. of parts | 14 | 5 | 64.3% |
| Assembly time (s) | 123.6 | 28.58 | 76.9% |
| DFA efficiency index % | 12.6 | 35.2 | 279.5% |

(a) (b) (c)

*Figure 5. (a) Moldflow simulation results (b) MAYA 3D animation (c) physical prototype including three suction head sizes*

### 4.3 3D Animation of the Device & Functional Physical Prototype

A 3D animation using *MAYA* was created depicting the tumour being supported whilst blunt dissection was used to remove the tumour, as illustrated in Figure 5b. Detailed 3D CAD models and their corresponding drawings were used to manufacture a functional prototype depicted in Figure 5c. CNC milling and turning were used to fabricate the stainless steel 316L suction tube assembly, whereas *Fused Deposition Modelling* (FDM) was employed to fabricate the three suction heads from ABS.

## 5 EVALUATION

A questionnaire based on the PDS requirements was prepared with the three different users in mind, in particular, the surgeons, the scrub nurses and the sterilization technicians. The 3D animation of the instrument and the working prototype illustrated in Figures 5b and 5c respectively were used in the evaluation. It must be mentioned that the aim of this evaluation exercise was to gather qualitative data rather than quantitative data, the key findings being:

1. The surgeons (n=2), felt that the instrument accomplished its primary objective, i.e. that of facilitating excision of lung metastases. One surgeon went as far as to say *"This is an important device because current instruments, which are not tailor made for this procedure, can cause fracturing of a metastasis"*.
2. The nurses (n=4) were impressed with the device and felt the modularity of the device would *"reduce surgery time therefore being beneficial to the patient"*.
3. All technicians (n=4) agreed the instrument could be easily sterilized.

## 6 CONCLUSIONS AND REFLECTIONS

It has been shown, that by the careful use of design tools, it is possible to navigate through the design cycle efficiently and effectively, resulting in a desirable surgical instrument useful to the relevant stakeholders in practice. Continuous communication with end-users throughout the different activities of the basic design cycle proved crucial in understanding what is expected from such an instrument. The novel characteristics of the developed surgical instrument included the use of snap fits to mount the suction head with the tube, thereby facilitating instrument sterilization and the fact that surgeons could choose different suction heads, depending upon the size of the metastasis.

As mentioned in section 1, this project was a result of internal collaboration between the Faculty of Engineering and the Faculty of Medicine and Surgery at the University of Malta. Certainly, joint supervision was of great benefit to the student as he managed to get the best of both worlds; in particular feedback on the application of engineering design tools and the accessibility of leading local surgeons at different activities of the design cycle. Such an internal collaboration led to the application of design tools to develop a high-value added product. A working prototype of the instrument was also fabricated and evaluated with a range of typical end-users; the promising results attained reflect that the instrument can be potentially commercialised. This pedagogic approach correlates with the *'Design Theory to Practice'* (DT2P) model (see Figure 6), whose goal is to allow design theory, in the form of a range of systematic methods, to result in design solutions/concepts that can be readily taken up by industry [12].

Of course, because it is a medical device, there are regulatory processes and clinical investigations that have to be completed before the technology can be made available on the market. Due to the restricted timeframe, the student did not have the time to delve into the business aspect of the instrument. However, the positive feedback which he received coupled with the potential market of this high-value added product, motivated the student to pursue a taught M.Sc. in *Integrated Product Development* (IPD), offered by the University of Malta. In this course, students have the opportunity to acquire knowledge on the business pillar of product development, which lacks in the bachelors four year mechanical degree course. This can be perceived as another spin-off benefit resulting from engineering design related projects which are conducted jointly between relevant faculties.

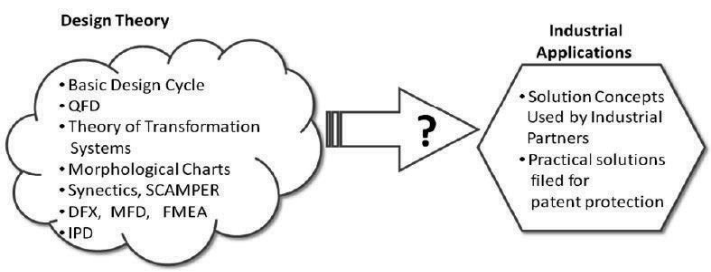



*Figure 6. Underlying principle of the DT2P model of design education [12]*

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# PERSONAS AND ROLE-PLAY HELP STUDENTS (AND DESIGNERS) EXPERIENCING REALITY

**Gerard VAN OS and Karin VAN BEURDEN**
Saxion University of Applied Sciences, Research Centre Design and Technology, NL

**ABSTRACT**
Many experienced product designers will recognize this from their starting days in the design world: how to understand the people (e.g. users, customers), environment (e.g. professional, home, outdoors) and problems or needs one has to design for.
This paper explains how we teach design students the necessary awareness and skills to learn and experience reality on their own. The paper explains how we mimic the reality of product design and how qualitative research leads to output like personas and use scenarios. These tools exist for some time, but we made them more practical for both students and designers of products for caregivers in home situations. The paper also explains how a role-playing or experience tool, one of the results of the RAAK-MKB Ontwerpen voor Zorgverleners ("Design for caregivers") project, can be used by students to understand hands-on what it means to be a member of the target group. The tool can also be used by designers to explain to others in the product team the specifics of the target group.

*Keywords: Experience, persona, qualitative research, use scenario, tool, role-play*

## 1 INTRODUCTION

The public RAAK-MKB Ontwerpen voor Zorgverleners ("Design for Caregivers") project (further RAAK-OvZ) [1] was initiated by the Chair Industrial Design of the Research Centre Design and Technology of Saxion University of Applied Sciences [2]. Short for "Regional Attention and Action for Knowledge circulation", a RAAK project aims to improve knowledge exchange between small and medium regional enterprises and Universities of Applied sciences. Partners in the RAAK-OvZ project were University of Applied Sciences Utrecht, Panton (design studio medical innovations) [3], Industrial Design Centre (design network, region Twente) [4], Carinova (regional home care organization) [5] and U-design (design network, region Utrecht) [6].
The main research question of the project was: "how to design new products that are in line with the wishes and thoughts of home caregivers". The project explicitly did not focus on the care in hospitals or specialized institutions, but targeted two distinct groups in home care giving: the professional caregivers and the voluntary or informal caregivers. The latter is a group of caregivers that have a personal, non-professional relation with the person that receives care. The Dutch word for this group is "mantelzorgers".
The project ran from September 2011 up and till September 2013, and consisted of eighteen sub-projects. Some sub-projects were about identifying and describing the target groups. Other sub-projects where about designing new products or services: an electronic device to increase the level of safety for caregivers or a small footprint hoist or patient lifting system for transferring people in and out of bed.

## 2 TOOLS

This section describes the main research tools introduced to students in our program: qualitative research, personas use scenarios and the experience tool. Section 3 then explains how these tools are applied in our educational environment and in the RAAK OvZ project.

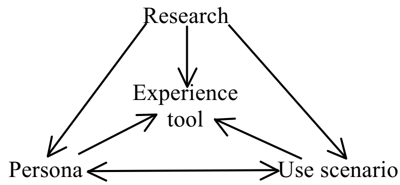


*Figure 1. Relation between the design tools*

### 2.1 Relation between tools

Before explaining each tool in detail, it should be clear that they are related as depicted in ***Figure 1***. The **research** tool is used to get to know the people, problems and domain. It's largely unstructured, and based upon observations and interviews. Part of the resulting research data is used to create **personas** that describe e.g. the whereabouts, demographics, problems, believes, etc. of the intended users. Other research data is used to create use cases or **scenarios**. These describe what the intended users want to achieve and how they get there. The **experience tool** then puts together research date, personas and scenarios and describes what happens between people or between a person and a product.

### 2.2 Qualitative Research

There are several qualitative research methods available: interview, observation, focus group, grounded theory, context mapping, cultural probes, to mention a few. The intention, however, is always the same: get in the head of actual people and find out why they do the things they do, how they do it and what they want to achieve by doing it. The answers to these questions drive design solutions. The best way get to that information is by observing how things are done and asking open questions. The participants are considered the experts in their domain, and the role of the researcher is that of an apprentice learning a new trade. In a later phase, when a prototype is available, the research focuses on the assumptions the designers made while designing the solution (prototype) and to what extend it works in the real world. Because of the state of the prototype or because the participant is asked to think aloud, it rarely makes sense to measure something like task time or speed of learning during the session.

### 2.3 Personas

Already used by many designers, it is worth mentioning that persona originates from ancient Etruscan and Greek words meaning "theatrical mask". In recent times Alan Cooper introduced it in software design with his book "The inmates are running the asylum" [7]. Since than, personas also got used in other design disciplines and in marketing as a method to give face to user or customer.

Design personas are created mainly from qualitative research. It is possible to create purely text or graphic personas. However, others in the product team will try to fill in the missing parts, thus creating their own image of the persona. A persona in both text and pictures communicates a much clearer image, leaving much less to the imagination and thus creating a better common understanding as to who the target people are. The visual part of the persona can be a ketch on paper, a photograph of a real person or even a mannequin (Dutch: paspop) dressed up like the target group. Background information is than added is text. A target group seldom can be described by a single persona. During the RAAK OvZ project, for instance, we found that an informal caregivers can be the oldest daughter but also the spouse. Two very distinct personas! Alan Cooper [8] recommends creating between three and seven personas.

Over the years, we have determined three persona flavours: the general persona described in this section, the product persona and the market or buyer persona. The general persona describes the target user group in broad terms and with general activities. From that, the product personas are examples of people actually using a specific product. The market or buyer persona depict the people that buy products and are not necessarily the same as the product or general personas.

### 2.4 Use Scenarios

Use scenarios, usage scenarios or use cases are not new and are aimed at describing a specific user-product-interaction. As with personas, use scenarios are visualizations of user-product-interactions, especially of common and critical ones, that need to be incorporated in the product (re)design. The main use scenarios are the answer to actual user needs or desires.

Our scenarios are graphic in essence complemented with explaining text, very much like a cartoon. With these cartoon like use scenarios all members in the product team get the same impression about the interaction. Instead of discussing different interpretations, the team can immediately focus on designing the right solutions.

The visualization of a scenario depends on the available time and resources: drawing them up on paper or e.g. Photoshop will be faster than making pictures or even a video. As a rule of thumb, personas and scenarios created very early in the project can be simpler and sketchier than the ones that are used to actually communicate with others outside the project team. Videos are sometimes used, but the results are not all satisfactory. Because of the sequential nature, it is more difficult for the viewer to get the full picture of the scenario in his head. A six to eight picture cartoon can be grasped in one view, regardless if it is a large foam board in the project room or on an A4-page in the milestone report.

### 2.5 Experience tool

Quite late in the RAAK-OvZ project the experience tool came to live in an attempt to communicate the research date, personas and scenarios. In essence it is a role-playing tool, where two (or more) people enact on the research data, the personas and the scenarios. The actors can be anyone in the project team and they have the opportunity to search for background information considering the characters. This includes facial expressions, body language and body postures.

During the closing conference event of the RAAK-OvZ project, two project members gave an example of this tool. One character was named Fatima, a female Muslim professional caregiver while the other person took the role of an informal caregiver. In the role-play both met to discuss several issues. Both players added "features" based on the role they played. Fatima e.g. didn't look the caregiver in the eyes and hesitated to accept the welcome hand of the caregiver.

We have only scratched the surface of possibilities, applicability and educational challenges of this tool. More research and experimentation is needed to find out what competences and talents need to be developed by the student-designer. Francis Stam, trainer of non-verbal communication and one of the designers of the tool, explains that especially the empathic abilities may need explicit development and training.

## 3 PROCESS AND EDUCATION

In an ideal world, all information and knowledge is available right at the start of a (design) project. In reality it is not, and experienced designers have learned by experience to deal with it. A design student, however, doesn't have that experience and has to become somewhat competent in a short period of time. He has to learn about e.g. conducting research, creating personas and scenarios, and almost at the same time apply that in design assignments. Quite a task for both students and teachers and one of the better ways of doing it is learning by doing or trail and error. The first thing students do when asked to find out how people e.g. work with a product, is to put together a (long) list of closed questions, This list is then put into questionnaire tools like surveymonkey [9] or thesistool [10]. When the results come in, they discover that they learn a lot about how people work with the product, but not what that is. At that point they realize that a different approach is needed to answer that question. The best thing we learned from education and research and design projects is for designers and students to go out in the real world at the very start of a project or assignment. Start with getting a scent of the intended users, the problems and the environment and then start searching and reading. This is especially true when entering new and unknown (market) segments: talking with two or three will bring designers and students up to speed for any research and work that follows.

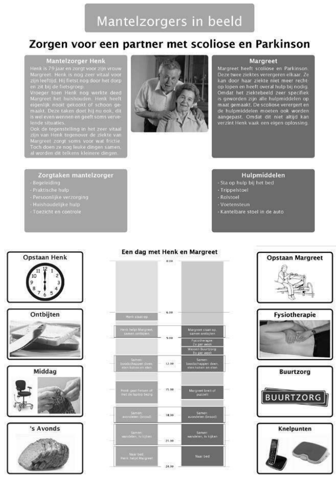


*Figure 2. RAAK-OvZ informal care giver Henk and activities*

As interview and observation are at the base of any qualitative research, students learn to become competent in setting up, conducting and analyzing observations and interviews. As a member of a larger research project, they can then learn to use additional like diaries, collages, grounded theory, etc.

During RAAK-OvZ, the student members of the team had the opportunity to go through the whole process from initial research to the newly end user products and the experience tool. The desk and field research led to personas and general use scenarios depicting the target group of professional and informal home caregivers (***Figure 2***). During the product design projects that followed, these personas and use scenarios were detailed to the product level.

The experience tool was actually triggered by another RAAK project: RAAK Vitale Ouderen project ("Vital Elderly") [11]. One of the deliverables of that project was an experience tool that enables designers to experience the consequences of having some form of physical restriction (handicap). The kit is build from material that can be bought at a local drug store or Do-It-Yourself market: security glasses for simulation visual problems, bandages for restriction of elbow and wrist movements, earplugs simulating hearing problems, latex gloves decreasing the sense of touch. The experience tool that emerged from RAAK OvZ enables designers and students to experience what it means do be a target user. Although only used once at the closing conference of the project, the first experience is that it adds to the understanding of the designers, students and other members of the team.

## 4 DISCUSSION AND CONCLUSION

To students, the methods discussed in this paper are not related to each other. They also have difficulties using the results for designing a solution. One reason could be that when they enrol, they think designing is about what they personally feel that is needed, very much like an artist. However, from the first class they take they are taught that design is about first getting a clear image about user and use. Only then they can start (re)designing a product solution. To do this, research is needed and personas and use scenarios have to be derived from that research. The experience tool than give the student first hand experience in what it takes to be a target user. All of these elements are preparations to actually design a user centred solution. To better prepare the student for what is to come, he should be informed differently prior to enrolling: This study it is not about creating products like an artist, but about user centred design that starts with gathering information from the field and using that in creating an optimal solution.

### 4.1 How we teach research

Teaching young people how to become a researcher is challenging both for the student and the teacher. The teacher cannot simply open his or her mind and let students copy anything that seems useful for them. Knowledge transfer and gaining competence has to be dosed and practiced, starting with the basics and gradually increasing in complexity.

The way we try and teach research skills is to focus on the process much more than result. In other words: not the result of the research is important (and graded), but the process and arguments that led to that result. The student has to answer questions like why the specific research method chosen, what research question needs to be answered and why. During a research assignment the student is coached and taught what other methods could be used and why. It is because of the process perspective, that it is important that the student learns and shows improvement. When the student is able to incorporate acquired knowledge with little or no coaching, than he or she is on the path of becoming an excellent (junior) research designer.

### 4.2 How we teach creating and using personas and use scenarios

Although we used personas and use scenarios a number of years in research projects and curriculum, the results are not all satisfactory. Because we ask e.g. personas and scenarios in almost all design assignments, students do get a better image of who the product users are and what they want to achieve. The ultimate goal is that students create personas and scenarios on their own initiative because they know they actually need, and not because we (tutors) ask for them.

Having said that, our observation is that creating personas and scenarios doesn't automatically lead to creating good solutions. What seems missing is the ability to make a grounded translation of what was found during research into design solutions. At present, we are still working on this one. One assumption is, and this is food for further development in both the curriculum and at the Chair Industrial Design, that we ask the wrong questions. Clayton Christensen proposes in "Finding the right job for you product" [12] that we should find out what job the user needs to get done for which a particular product is hired. Although the article was written from a marketers perspective, the same question applies to user related research and design. The approach Christensen proposes uses qualitative research figuring out what users want to achieve and what they use now to achieve it. In future Chair research projects and Industrial Product Design classes we will be experimenting with this approach to 1) find out how and where this can be used, 2) how it influences the vividness an reality factor of personas and scenarios and 3) how it supports designing proper design solutions.

### 4.3 How we think teaching the use of the experience tool

The experience tool in this paper was never part of the curriculum. When we use it, it will be an experiment aimed at validating its added value. The experience tool possibly calls for the development of the empathic skills of students (and designers). For now, the best way we can think of is to simply do several role plays: learn by doing. The players have to find background information about the characters and use that in the specific situation that is to be played out. Positive feedback from tutor and fellow students will bring the student to the next level. It is crucial that students do several role-plays: only then can they apply new knowledge, show improvement and gain competence.

As the present experience tool is based on the home care environment, the description should be generalized. Another thing to find out is what is the right time and place to apply the tool: how much data should be available and how many personas and use scenarios should be visualized. Also: the present tool is about the interaction between people. Experimentation is needed to find out the extent to which it can also be used to experience the interaction between a human and a product.

### 4.4 Wrap-up

All of the above is a lot of work, so why not stop after creating personas and scenarios? The answer is actually quite simple. Only by actually applying the results of research, the personas and scenarios in actual role-play, a truly user centred and user-friendly solution can be designed. So: Yes, this is quite some work, but it leads to products that users want and like. The process leading to such a product will be smoother and shorter. Once results must be communicated to others in the project team or in the company, all of the above will help making a common and concise picture of who the target user is and what problems to solve. Personas, scenarios and role-plays are vivid and immediately recognizable, and complementing this with written product specifications saves a lot of discussion during product development.

In a way, the movie "Kitchen stories" [13] is a perfect example of how research results in role play. In the movie, researcher Folke Nilsson has to sit on an umpire's chair in a small kitchen to observe Isak

Bjørvik. When Isak dies, Folke seamlessly takes his place and acts like Isak to all of his friends and neighbours. The movie is mandatory for the students in our fourth year research class.


*Figure 3. Kitchen Stories*

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# INTEGRAL DESIGN: THE NEW NECESSARY PROFESSIONAL SKILLS FOR ARCHITECTS AND ENGINEERS FOR THEIR ROLE IN SUSTAINABLE DEVELOPMENT

**Professor Wim ZEILER**
TU Eindhoven, The Netherlands

**ABSTRACT**
The built environment is one of the most important areas of sustainable development. New strong demands for a more sustainable built environment led to a more complex design process. To cope with this complexity architects and engineers have to operate together earlier in the conceptual building design process. As a consequence architects as well as engineers have to develop new skills. Also the architect has to learn, to not only share his ideas in the conceptual design phase, but to really open up his mind and to truly design together with the engineers. Designing becomes a team effort already in the conceptual phase of design. To support these diverse multidisciplinary building design teams a supportive design method was developed in cooperation with the Dutch professional organizations of architects and consulting engineers. The method is being used in a workshop Integral Design for master students at the Faculty of the Built Environment of the University of Technology Eindhoven. In this project students from different disciplines have to design a net Zero Energy Building within one semester. The design tool enables not only to support the design team during the conceptual design phase, but also to study the process within the design team in detail. Especially interesting is to see whether the architectural students would really work in a kind of open dialogue with the engineering students or that they would behave in a more traditional dominant role in the conceptual design phase. It proved that architects played a dominant role in defining the functions to be fulfilled by the design. Overall the attitude of architectural students and engineering students has to change to allow real integral design processes in which the disciplines have a real open mind towards each other without any dominance.

*Keywords: Architecture, Engineering, Integral design, Morphology*

## 1 INTRODUCTION

Although, sound decision making during conceptual development requires not only shape design knowledge (architect) but also technical expertise(engineers) as a consequence interaction between all relevant domains should be and is common understanding and practice in building design, this is not the true practically situation. However, in daily building design practice this is still quite problematic. The construction industry is in the early stages of a revolution to reinvent the design process that was used before the large scale application of HVAC systems (Heiselberg 2007). In contemporary building design the role of architects and traditional discipline based consulting engineers are changing. For a more sustainable future, the built environment is one of the most important areas to work on for sustainable product innovation. The built environment uses in the western world 40% of our energy for operating as well as another 8% embodied energy by the used building materials and their production process. In response to climate change and 'peak oil' architecture should encompass the environmental task of design a low carbon built environment (Chen et al. 2011). As such, architecture has an important role in directing sustainable development (Taleghani et al 2010). Within the European Community the member stated declared that all new buildings should be nearly energy neutral by 2020 and that they want to achieve an energy neural built environment by 2050. This led to the development of Zero Emission Buildings: a building which emits virtually '0 (zero)' carbon dioxide (Kang et al 2010). However this new target in building design ZEB, requires totally different approach from conventional building in terms of design, construction and operation (Ritter 2010).

These new strong demands for a more sustainable built environment lead to a more complex design process. The increased complexity of building design inevitably calls for more design collaboration (Lee and Jeong 2012). To fulfill the demand for nearly Zero Energy Buildings there is a need for synergy between the architectural and engineering domain. To cope with this complexity architects need more support from specialized engineers. The different expertise of engineers must be used more effectively especially in the conceptual design phase to reach for new solutions. This has consequences for the role of the engineers involved; they have to operate early in the conceptual building design process and act more as designers and less as traditional calculating engineers. As a consequence engineers have to develop new skills. Also the architect has to learn to not only share his ideas in the conceptual design phase but to really open up his mind and to truly design together with the engineers. It is important that the architect is no longer the one who leads the design process but that the team of architect and engineers leads the design process: Designing becomes a team effort already in the conceptual phase of design. Engineering consultants now have to do more than was traditionally expected from their engineering discipline, as stated by one of the major Dutch building consultants firms (DGMR 2011). Architect and engineer should work together from the very start of a design project and try to reach synergy by combining the different knowledge and experience of the different disciplines. One of the complicating aspects in building practice is the different cultural back-ground of architects and engineers and their different approaches to design. Still synergy between the different disciplines involved in present building design processes is necessary to reach the innovative highly sustainable designs. Trebilcock (2009) concluded that when designing sustainable energy-efficient buildings it requires that architect and engineers overlap their knowledge and skills and share the character of a designer (Brunsgaard et al 2014). King (2012) states that in order to do anything meaningful in terms of moving to low carbon society, we need a consistent framework and design method, within which we can apply knowledge embodied in a design team. The solution for improving the overall quality of building design might lay within the design team itself and letting the design team functioning as a real team. This implies equality and mutual respect between the various disciplines within the design team. However, this is not something easily achieved and design tools and methods might help the process. However, proper design tools and working methods are needed which could help architects in the design process (Kanters et al. 2014). To support these diverse multidisciplinary building design teams we developed a supportive design method in cooperation with the Dutch professional organizations of architects and consulting engineers.

As stated by Janet Beckett, director at Carbon Saver a consultant company specialised in Low Carbon Building design and building engineering physics, there could not be a better time than now in time of global change to implement a paradigm shift within building design – we cannot continue in the same vein (Beckett 2012). Earlier dialogue and true cooperation in the project design means it is easier to build on sustainability, and add innovation and engineer integrated solutions (Beckett 2012). A new kind of architect is needed, who can accept the principles of engineering alongside the building aesthetics. A new generation of architects to be inspired by engineering and science, according to Beckett (2012), willing to listen to concepts and ideas that can be both beautiful and useful as well as sustainable. Also a new kind of engineer is needed, one who is better able to communicate about the realities of how engineering services impact on the building and not just solving problems.

## 2 METHODOLOGY

In the early 1960s researchers and practitioners began to investigate new design methods as a way to improve the outcome of design processes. Since then, there has been a period of expansion up to the present day (Cross 2007, Chai and Xiao 2012, Le Masson et al. 2012, Ranjan et al 2012, Gericke and Blessing 2012). In the projects designed (and built) in the early 2000s, architects started to adapt their usual design process (traditional design process) by consulting engineers in an earlier stage than normally done. In sustainable building projects designed later, many architects qualified their design process as an Integrated Design Process (IDP): the architects mentioned the early engagement of engineers in the process as a clear sign of this (Kanters et al 2012). This early collaboration with engineers was found to be crucial in order to develop and implement sustainable architecture such as solar integrated architecture. However, this collaboration in the early design phase was not always easy for the architects: engineers ‘spoke another language’, were often ‘too specialised’, and ‘not willing to compromise on certain issues’. So, the building design process has become more heterogeneous, with several diverse actors involved such as architects, engineers, contractors and clients. In effect, in order for the contemporary architect to provide a cutting edge concept for a zero energy building, he must view the engineering disciplines as de facto co-designers with integral roles within the design team. Viewing engineers as co-designers has a number of consequences worthy of note. First, the relevant engineering knowledge to work towards zero energy buildings is dispersed throughout a number of engineering sub-disciplines, which implies the need for a variety of engineering disciplines to be included in the design team, e.g. structural engineers, HVAC(Heating Ventilation and Air-Conditioning) engineers, Building Physics engineers etc. Second, to gain the maximum value from this engineering knowledge and to make the design process as efficient as possible, the engineering disciplines must be included in the earliest possible stage of the design process, which can be understood as the conceptual design stage. Third, both the architect and the engineering disciplines will have to learn new skills in order to function productively in a design team scenario. The engineers will have to operate less as traditional calculating engineers, and more as designers who contribute to a shared team concept. Conversely, the architect will have to learn to be much more inclusive in the design process and allow the engineering disciplines to actively contribute to the dynamic design process rather than rely on engineers to simply verify or optimise his own design contributions. Finally, in order to facilitate the inclusion of engineering knowledge into the design team, it is necessary to provide the design team with simple and intuitive methods and design tools that the engineering disciplines are comfortable using.

In the Netherlands methodical design is a quite familiar design method (Zeiler and Savanovic 2009). The methodical design process is a framework application-independent principle with its connection to the general system theory and has some exceptional characteristics (Blessing 1994): it is problem oriented and distinguishes, based on functional hierarchy, various abstractions or complexity levels during different design phase activities. This design method was further extended by us through the intensified use of morphological charts developed by Zwicky (1948) (Zeiler and Savanovic 2009, Savanovic 2009) and the specific use of a morphological overview derived from the morphological chart. The morphological chart is formed by decomposing the main goal of the design task as formulated in the program of demands into functions and aspects, which are than listed on the first vertical column of the chart, with related sub solutions listed on corresponding rows. The use of the morphological chart is an excellent way to record information about the solutions for the relevant functions and aid in the cognitive process of generating the system-level design solution (Wynn and Clarkson 2005, Ritchey 2010). The morphological chart (MC) to visualize sub-solution alternatives plays a central role in the integral design approach for design teams. It helps architects and engineers with their new role in the conceptual design phase as it enables to structure each perspective on the design task as well as to structure the available domain knowledge. The description of the morphological overview may read as minor implementation difference of the old morphological matrices. However based on the applied Integral Design method to structure the design process and using its design tools, the effect of using the morphological overview can be presented in analogy with the model of Badke-Schaub et al (2007), see Fig. 1 (A) and (B).

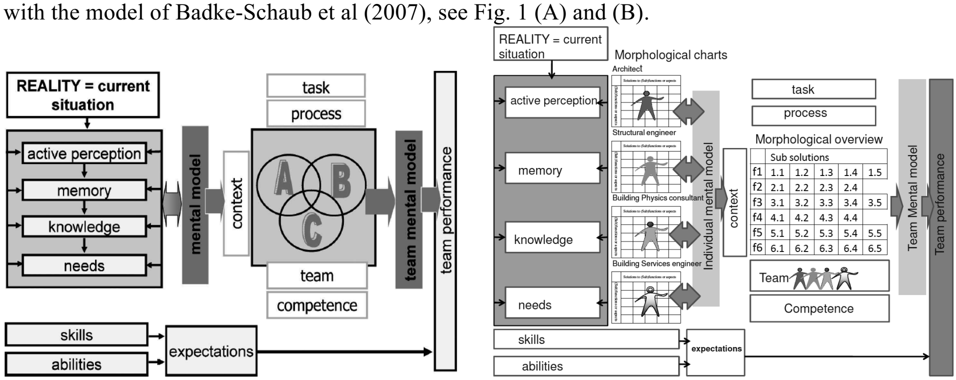


*Figure 1 (A) Mental model concept (Badke-Schaub et al 2007) and (B) Design Team mental model Morphological Overview in analogy with the model by Badke-Schaub*

Based on the given design task, each design team member perceives reality due to his/her active perception, memory, knowledge and needs. The morphological charts represent the individual interpretation of reality, leading to active perception, stimulation of memory, activation of knowledge and defining of needs, see Fig. 1. Within the morphological overview these individual stimuli can be combined to those of the whole design team. As such the morphologic overview can be used by the designers to reflect on the results during the different design process stages. This illustrates how the mental models in teams develop. It shows that the morphological charts and morphological overview of the Integral Design method can be used to make transparent parts of the Team's Mental Model. The individual morphological charts of each individual designer represent their active perception, their activate part of their memory, their individual knowledge used as well as their interpretation of the design needs. These individual morphological charts can be combined by the design team to one morphological overview, see Fig. 2. This morphological overview is than the representation of the design team's interpretation/perception and activated memory/knowledge.

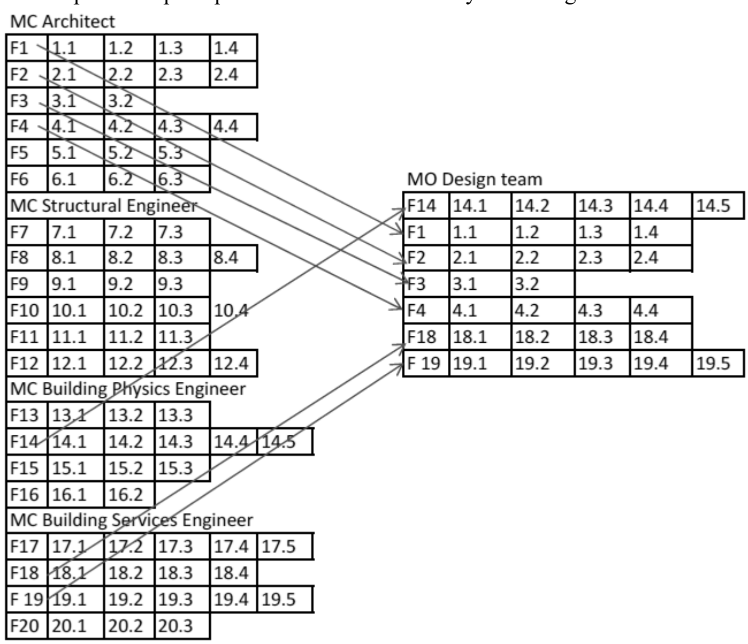


*Figure 2. The transformation from the individual morphological charts towards the design team's morphological overview*

## 3 EXPERIMENTS

In the last four years each time a Master Projects Integral design was held 6 teams of 4 students from different disciplines participated: architecture, structural engineering, building physics and building services. The master student's teams work together for a semester on a design task. The location and the type of building of the design brief changes every year but the goal of the design project remains the same: to design a net Zero Energy Building. The Master project starts with a workshop of two days. The design tasks during the two days were on the same level of complexity and had been used, tested and evaluated in professional workshops as well as in student workshops (Savanovic 2009). The application of morphological overviews during the setup of the design session enabled structuring of design functions/aspects and the generated (sub) solution proposals. The workshops provided a good test bench to experiment with different interventions within the design process as well as to analyse the results step by step during the design process. In this paper the analysis is limited to the results of the workshops in 2013. In total 6 multidisciplinary student teams were analyzed, with a specific focus on the interaction between the architectural student and the engineering students.

## 4 RESULTS

Some of the functions mentioned by the students in their own morphological chart became part of the morphological overview of the design team. This made it possible to look how many of the by students of a specific discipline mentioned functions became actually part of the morphological overview of the whole design teams. As shown in Fig. 3 A in 4 out of 6 teams the architectural students define 50% or more of the functions within the morphological overview. Furthermore, as shown in Fig 3 B. 60 % of the first mentioned functions and even 100% of the second mentioned functions came from the architectural students. Al indications for a clear dominance by the architectural students in the process of defining the functions to work on in the conceptual design phase.

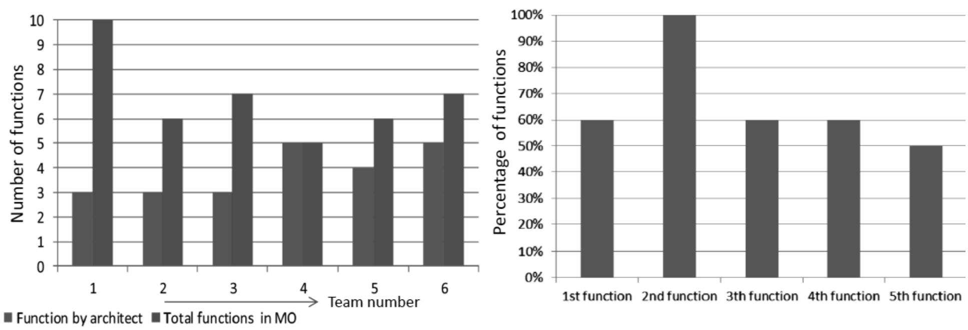


*Figure 3 (A) Number of functions mentioned by the architectural students (B) Percentage of functions mentioned by the architectural students*

## 5 DISCUSSION AND CONCLUSIONS

In the last 10 years Master Projects Integral design were held. Our design approach showed that it is possible to interactively engage engineers within the conceptual building design phase with other disciplines. Although the application of morphological charts for concept selection is common practice, however it’s use to form a morphological overview based on the individual morphological charts is new. This enables to reflect on the process and to make the link towards the mental model of Badke-Schaub (2007). This is the major contribution of this research. As such everything becomes more transparent during the conceptual design phase and that was one major goal to achieve. This enables it to study specific effects. The results shown here from the 2013 workshops clearly indicate the dominance of the architectural students in defining the functions to work on in the conceptual design phase compared to the engineering students. So definitely it is necessary to develop the skills of both groups to be able to work in a more open and equal way to realize the necessary synergy for integral design.

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# DEMANDING IT ALL FROM THE NOVICE MECHANICAL ENGINEER THROUGH DESIGN AND MANUFACTURE

**Marc MASEN[1], Andrew BRAND[1], Yanliuxing YAN[1], Julie VARLEY[1], Peter SPENCE[1,2] and Peter CHILDS[1]**
[1]Imperial College London, SW7 2AZ, UK
[2]Royal College of Art, London, SW7 2EU, UK

**ABSTRACT**
A core design and manufacture group project has been run in the second year of the Mechanical Engineering undergraduate programme at Imperial College for over two decades where students are required to develop highly loaded rotating machinery, such as a pump or a winch, early in the second year of their undergraduate study. The aim has been to provide a practical opportunity to apply and develop skills learnt in the first year and to provide the experience of manufacturing, operating and testing what has been designed. While these projects have been a mainstay of the educational experience for many years, there has been a persistent concern that the projects are deterministic and highly constrained. The course team and student body have debated and now implemented a new project that is both less constrained and more appealing to the student cohort. In this project the students are tasked with developing a transmission for an electric scooter. The project has resulted in a significant diversity in designs and, importantly, the students embracing the curriculum content with fervour. The challenge still requires attention to the application of fundamental mechanical engineering principles such as transmissions, solid mechanics and materials, but also focuses on electronic control systems, battery and motor characteristics, high current and power, health and safety and a range of transferable skills. The multi-disciplinary nature of the project combined with an appealing application has resulted in a highly engaged year group. This paper reports on the project and includes an analysis of the diversity of designs and student effort.

*Keywords: Design, make, test, manufacture, engineering, e-scooter, project*

## 1 INTRODUCTION

The modern mechanical engineer is expected to possess a combination of technical expertise and a range of ‘soft skills’. These requirements for engineers have been extensively debated and defined by national bodies such as the Royal Academy of Engineering and the National Academy of Sciences, as well as professional institutions and national accrediting bodies. In 2004 the National Academy of Engineering [1] defined the attributes of the engineer of 2020 to include mathematical and science skills as well as creativity, practical ingenuity and communication, business and management skills. This required skill set is reflected in typical undergraduate Mechanical Engineering curricula, which contain technical foundation courses as well as applied and integrative components. The foundation courses, such as Thermodynamics, Solid and Fluid Mechanics and Materials, are often taught in a structured and 'linear' way, using a course plan that emphasizes the gradual build-up of complexity, whilst focussing on the understanding of the mathematical and physical backgrounds and solving a set of well-defined problems with clear boundary conditions. Next to creativity and technical drawing skills, important aspects of the design part of the curriculum are the integration and application of the knowledge acquired in the separately taught foundation courses and the ability to define and quantify the specifications and boundary conditions associated to a certain problem. In other words: in the design projects the students are given engineering freedom to demonstrate their capabilities in a combination of technical and non-technical subjects. An important part of a design engineering project is to work through a series of processes that are focussed on bringing structure to the entangled compound of the stakeholder’s demands and requirements and technical, physical and economical

possibilities and restrictions. Such a process is recursive, retrospective and involves a number of iterations. In educational design projects this inherent non-linearity is even more evident: 'learning by doing' plays an important part in a student's experience, which means that regularly an incorrect path may be followed. All these aspects make educational design engineering projects seem time consuming and inefficient by participating students and even by educational staff. Within an educational plan, the time that the students are expected to spend on each course is limited, and one way around the perceived inefficiency of design projects is to provide the students with a highly constrained brief in terms of design freedom, creativity, solutions, materials and complexity so that the students will be forced to gradually proceed through the design process. Furthermore, time expenditure on tasks that are not directly perceived as being academic (such as manufacturing and planning) is often limited or even omitted, whereas these subjects will provide students with valuable insights into the practicalities and feasibility of their designs.
The viewpoint outlined so far can result in design projects that are 'educationally safe': projects that are restricted in scope and have a large number of pre-set milestones driving the students towards a pre-determined outcome, focussed on mid-twentieth century engineering.

## 2 THE E-SCOOTER PROJECT

A core design and manufacture group project has been run in the second year of the Mechanical Engineering undergraduate programme at Imperial College for over two decades where students are required to design, build and test highly loaded rotating machinery. The aim has been to provide a practical opportunity to apply skills learnt in the first year and to provide the experience of manufacturing, running and testing what has been designed. Projects along these lines have included the design and manufacture of pumps and winches, see for instance [2], and there has been a persistent concern that the projects are deterministic and highly constrained. While this may represent a common experience in certain industries feedback, from students and some staff, indicated a preference for a more inspirational and aspirational problem that is more closely matched to the student's areas of interest and way of life. This lead to the course team and student body to debate and implement a new project where the students are tasked with developing, i.e. designing, manufacturing and testing, a transmission for an electric scooter. Introducing a new project is always a concern in a successful and established curriculum, as there are pressures for any new project to be as good as, or better than its forerunner. Here, use was made of a master's project prototype to gain confidence in the technology, followed by a detailed consideration of the student experience and the pedagogic journey.

### 2.1 The student experience - rationale behind a scooter

The electric scooter as a design project was suggested by an MSc student. The student's objective was to develop a portable means of transportation for a commuter to be used in an urban area such as London, to travel from a stop on the public transport network to the final destination. This means the topic of the design project is close to the day to day living experiences of the students, who typically travel to the college using the London Underground. The MSc student's prototype project was developed in a period of four weeks, during which the electric drive train was designed, manufactured, assembled and mounted onto a purchased push scooter. Following the successful development of the prototype, the project was introduced to the 2013 cohort of 146 second year undergraduate students in Mechanical Engineering. Project teams of 6 students were composed, with each student expected to spend a total of 90 hours on the project over a period of 14 weeks.

### 2.2 The project brief

The project brief handed to the students contained seven pages of text and imagery with background information on the project. This elaborate document provided only descriptive and non-quantified details, forcing the students to initially focus on the development of a product design specification; for example: the specified objective was to develop an electric scooter that would be able to provide transport from South Kensington Underground Station to the entrance of the Mechanical Engineering Department of Imperial College on Exhibition Road, a distance of about 500 m and a journey very familiar to the students, but further characteristics and the related requirements such as the distance and the time available for this journey were not specified. The students were provided with a push-scooter, an electromotor, a battery with casing and wires and an electronic speed control system including a thumb-throttle. Structural components had to be made out of steel or aluminium using the manually operated equipment and NC manufacturing techniques available in the department's student workshop whilst the transmission components (gears, chains, sprockets, belts, etc., depending on each group's design) were to be sourced from one dedicated supplier. The provided motor was a 1500 W, 60 A high speed, low torque motor that is normally used for radio controlled helicopters. The no-load speed of the motor is about 6200 rpm, which with a diameter of the driven wheel of 120 mm would result in a theoretical top speed of the scooter of 135 km/h. Irrespective of the required power, this implied that a direct drive solution is not possible and that a transmission with a reduction in the order of 1:6 to 1:10 was required to between the motor and the wheel. The only other restriction detailed in the brief was the compulsion to use a shaft that was fixed to the rear wheel. No other restrictions were made, enabling the students to freely develop their concepts during the first four weeks of term.

### 2.3 Pedagogic journey – project structure and phases

The project duration was 14 weeks, starting at the beginning of the student's second year in October. Three deadlines were set: a design gateway after four weeks, a design report in week 10 of the project and the hand-in date for the finished scooter transmissions at the end of week 14. During the initial stage of the project the students focussed on developing their design, as well as attending project related lectures on subjects including design, computer aided design and manufacturing, transmissions, various machine elements, stress analysis, fatigue, electric motors, batteries and reporting techniques. The expected time expenditure during this phase of the project was 10 hours per person per week. Experienced tutors were available for advice regarding practical design considerations and to provide support and guidance regarding the computer aided design software. These tutors took a passive role in the design process and were not actively providing design solutions. The intensive design phase was concluded with a 25 minute design review, during which each group presented their work to a panel of staff. The review panel asked questions regarding the design specification, the concept sketches and the followed selection procedure, the stress and fatigue calculations and the technical drawings. This gateway review provided a formal 'go or no-go' for the individual groups to proceed to the manufacturing phase. The discussions with the review panel were formative, meaning no marks or grades were awarded and the groups were free to use the provided feedback to alter their designs. The design stage of the project was concluded with a 25 page group design report, to be submitted 5 weeks after the design gateway review, discussing the product design specification, the generated concepts and the detailed design, including the stress and fatigue analysis, manufacturing considerations and the project planning. This report counted for 40% of the total mark for the project.

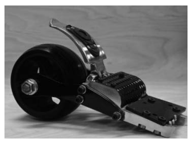
Following the design phase, the students spent a period of 10 weeks with a focus on manufacturing the designed transmission components [3]. The time the students were expected to spend on the project was significantly reduced, to an average of about 5 hours per week. A bench test set-up was available to test the performance of the manufactured product and the majority of the groups decided to make minor adjustments based on the outcomes of the bench testing, for instance because of a too small clearance between a moving component and the rest of the construction. At the end of the 10 week manufacturing period, the scooters were handed in and stored until a scooter test event at end of the year: the day after the final exams will be available for minor adjustments and preparing the scooter for testing and a day later the scooter test event will take place on a closed circuit in a square on Imperial College's South Kensington campus. This event is the unofficial end of year event for the second year students and is subject to the appropriate risk assessment and health and safety structures, with the departmental safety officer being part of the test event safety panel. Next to the safety aspects of the developed scooter, focus points will be the performance of the transmission in an endurance test and the manufacturing quality, forming the remaining 60% of the total mark awarded. The winners will have their names added to the golden scooter trophy which is displayed in the Department.

## 3 REFLECTION AND LESSONS LEARNED

### 3.1 The developed scooters

The complete project resulted in a wide variety of design solutions, and only a few of the scooters manufactured looked similar. The competitive element of the project resulted in the teams being engaged, but also operating quite secretively and not willing to share ideas with other groups. The required transmission ratio was achieved with either a one-step or a two-step reduction; some designs placed the motor behind the wheel, whereas others used the available space under the footboard. The photographs in Figure 1 provide an impression of the variety of designs. Designs can arguably be classified in groups, ranging from '*minimalist*' (Figure 1(a) and (d)) and '*simple and compact*' (b) and (c) to '*function before form*' (e) and '*large, bold and emphasizing'* (f). The majority of the groups (18 out of 24) decided to develop a transmission using a belt drive, whilst two groups decided to use a chain drive, two groups utilised a gear transmission and a further two groups opted to use a combination of a chain and a gear to reduce the motor velocity in two steps. The average mass added to the scooter was about 3300 g, ranging from a minimum of 1880 g to a maximum of 7000 g. The average expenditure, using standard university suppliers, on components such as bearings, sprockets, chains, gears and belts was £57.91 and also on this aspect the groups showed a rather large variation; some groups spent £32, whereas the top-spending group developed a two-stage reduction with a combined sprocket and chain transmission for more than £120.

*(a): belt drive with motor behind wheel.*



*(b): belt drive with motor behind board.*

*(c): gears with motor next to wheel.*

*(d): belt drive with overhung shaft.*

*(e): chain drive with motor under board.*

*(f): belt drive with motor behind wheel.*

*(g): a scooter in use.*

*Figure 1. Examples of developed scooters*

### 3.2 Staff reception and perception

The e-scooter project replaced a long-running project that had been optimised over the years it ran. In the previous long running project, tutors knew what questions to expect from the students and the workshop staff knew of most design related manufacturing issues related to the project. Consequently, the introduction of the e-scooter project encountered some resistance and conservatism, mainly relating to expected issues that would be encountered during manufacturing and the expected time that the students would spend on the design and manufacture of their scooter; time that they consequently would not be able to spend on their other courses. The complete freedom given to the students regarding their component design could result in a large variety of parts with complex shapes to be manufactured, and when these parts need to be clamped on the machines using jigs that have to be custom manufactured, the required time for manufacturing could be extensive. Therefore, the need for proper jigging was repeatedly mentioned during the tutorials and the CAD/CAM lectures so that the students could take this into account. During the project, members of staff became very engaged in the project and the main point of attention for the involved design tutors was to maintain a good balance between providing feedback and actively participating in the design project and providing solutions.

A second consequence of replacing a long running and rather restricted project by a project that allows more freedom in design was that a number of unexpected minor technical, educational and organisational niggles occurred during the project. These ranged from the perceived health and safety concerns related to the use of a high current, high power drive train to the availability of components and differences in guidance provided by the different tutors. Students were actively encouraged to report any issues they encountered and developments within the project were continuously monitored. Feedback from students, tutors and teaching staff was used to continuously control and amend aspects of the project and these changes were communicated back, thus creating awareness of the actions that were taken. This flexibility of the organisation of the module and the direct actions taken contributed to the positive attitude of the students towards the project.

The use of high power, high current components with their apparent safety issues and risk of personal accidents resulted in a range of concerns. It is necessary to be up front and rigorous on health and safety protocols with both colleagues and students. Risk assessments were an integral part of the development process of the module and lectures on batteries and motors not only focused on theory, successful applications and best practice but also illustrated the potential risks. Such an approach enables projects such as this to be implemented.

### 3.3 Student's view

In a short survey at the end of the project, feedback from the students on the topic of the project, i.e. developing a transmission for a scooter, was very positive, with 97% of the second year students who participated in the survey stating a preference for developing a scooter transmission over previous design project topics, such as a pump or a winch. In the official student survey, the scooter project received a 68% positive overall approval rating from the students, with a further 23% of students being neutral. While these numbers are not overwhelming favourable, it needs to be recognised that the student group is large, 146 high-attaining and demanding students, operating within a culture where analysis is the dominant mode of operation.

Based on questions asked at tutorials and follow-up discussions with students the main aspects of the design process where the teams appeared to be encountering challenges during the project were:

- Dealing with multi-disciplinary subjects.
- Estimating the requirements for properties that were not quantified in the project brief.
- Design for manufacturing and assembly
- Cooperating in a team and division of tasks.
- Adhering to the project time planning.

#### *3.3.1 Dealing with multi-disciplinary subjects.*

The entry requirement for participation in the project was the successful completion of first year foundation courses, and even though all students passed these courses, the integration of the knowledge of the various subjects showed to be an issue. For example, the students had been taught about stress analysis (see Childs [4]) as well as transmission elements before commencing their work on the project but the students did not consider using beam theory as an estimate of the bending stresses that occur in gear teeth.

#### *3.3.2 Estimating the requirements for properties that were not quantified in the project brief.*

As stated above, the brief provided had a descriptive non-quantitative nature, and the project teams had to expand upon the details provided in the brief to define their product design specification, and make some assumptions and reasonable estimates to be able to start the design process. This turned to be a challenge for some groups, who got stuck in lengthy discussions without coming to a conclusion whereas other groups quickly managed to perform some simple experiments and a range of order of magnitude estimates, prior to launching into overall concept designs and general arrangements.

#### *3.3.3 Design for manufacturing and assembly.*

Even though the concepts of design for manufacturing and design for assembly were repeatedly mentioned in the supporting lectures, the manufacturing sessions in the workshop provided valuable lessons for the students. Every group reported delays because of ill-defined tolerances, poor manufacturing precision or the design being impossible to assemble after all parts had been manufactured. As this project represents the first highly stressed, rotating machinery item that any of the students have designed and then made, such issues and challenges are to be expected, and form a natural part of the learning experience, prior to the students engaging in further projects and professional engineering where right-first-time expectations apply. The bench testing sessions provided further opportunities for feedback on the developed transmissions, with a focus on the machine operation and dynamics, including sharp edges, non-alignment and too small clearances.

#### *3.3.4 Cooperating in a team and division of tasks.*

At the start of the project the 148 students who were signed up to participate were divided into twenty teams of 6 students and four teams of 7 students. Due to last minute non-attendance of students, two groups of initially 6 students were reduced to 5 students and because of scheduling restrictions these two groups could not be replenished using students from the larger groups. However, the groups composed of 5 students appeared rather successful, whilst the groups that were composed of 7 students were the ones that complained about difficulties in team management, division of tasks and non-commitment from individual team members. This observation ties in with published research on optimum group sizes, where the most common and preferred group size for projects of this size and duration is 5 or 6 students [5], [6].

#### *3.3.5 Project management and adhering to the project time planning.*

All groups made a detailed project plan at the start of the 4 month project. This plan included a Gantt chart with milestones and deliverables. However, the students treated their plan as a deliverable of the project and not as a tool for their project management. Consequently, many groups did not manage to adhere to the developed project plan and only flagged issues a few days before deadlines. Planning a long-term project remains an issue for teams inexperienced in design and group work, with many students being prone to only focus on the subject or course with the closest deliverables. As the project was set-up with only three deadlines (the design gateway, the design report and the final scooter submission) over a four month period with the students being responsible for their detailed planning, on-time delivery and continuity of work flow was an issue, with only 33% of groups managing to deliver the scooter on time and only two groups (8% of groups) flagging this up as an issue two weeks before the project due date. These planning issues may be solved by an increased formative (i.e. non-marked) focus on the detailed weekly planning during the manufacturing phase of the project and the introduction of weekly pulse updates, either using an online tool or in tutored sessions, where deliverables, milestones and dependencies are commented upon and status updates are given.

## 4 CONCLUSION

A new design and manufacturing project has been introduced for second year undergraduate students in Mechanical Engineering. The project aimed to move away from 'traditional' mechanical design education by defining a project with a multi-disciplinary nature and an application that aimed to appeal to the students. The objective was for the students to experience a full design, manufacture and test project without the restrictions that are usually associated to such projects in an educational setting. Main learning points were threefold: firstly, students will assume a positive attitude towards a project that is not fully optimised yet, when their feedback is taken seriously and reacted upon. Secondly, that apparent health and safety issues can be managed by adopting rigorous procedures. Thirdly, the project suffered from poor project planning by the students, resulting in poor on-time delivery of the developed transmission modules. This could be solved by additional attention to overall project management and detailed manufacturing planning. It can be concluded that the introduction of the scooter project resulted in a highly positive and engaged year group.

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## Chapter 16

# TEACHING DESIGN EDUCATION METHODS

# EXPLORING THE EVOLUTION OF THE MOUSETRAP

**Gunnar GUNDERSEN**
Oslo and Akershus University College of Applied Sciences

**ABSTRACT**
This paper contributes to a pedagogical approach to teaching design related to social development by presenting and discussing the technical-solution and design evolution of a simple, everyday product. There is a need to explore the influence of social developments on approaches to product development and design solutions. It is important that students experience and observe how social conventions influence design. This paper investigates whether the evolution of the mousetrap has been driven by highly pragmatic and ergonomic influences or by certain social developments influencing how the (Western) world behaves towards fundamental questions, such as the issue of death. A case study of mousetraps focuses on what has been a principal solution of mousetrap construction from the first patented trap in the early 1900s to the latest models: a stroke against the neck of mice. How has the evolution of this solution been expressed in the objects? Immaterial values are reflected in the traps, and this case study shows how social norms can outweigh technical and ergonomic considerations in product development. Describing and analysing the history of the trap and considering relevant theory can have an impact on design students to reflect more on the market and social awareness. Using specific and typical examples from the history of the mousetrap and visually showing how the development of the trap over more than 100 years will contribute to understanding the complex issues involved in simple, everyday objects.

*Keywords: Anonymous design, simple everyday objects, evolution, influence on the design process*

## 1 INTRODUCTION: THE DEVELOPMENT OF AN EVERYDAY OBJECT

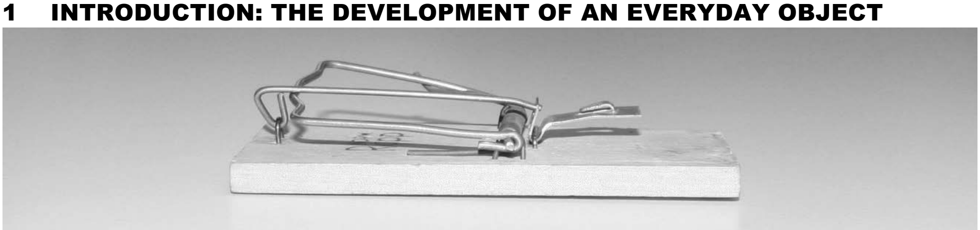


*Figure 1. The mousetrap stroke design*

The aim of this paper is to analyse the development of an everyday object: the mousetrap. This device has an anonymous design, is often mass produced and is primarily based on the requirements of function, simplicity and low cost. The construction of this object consistently follows these principles, which makes it transparent and, therefore, an interesting research object. Nothing—not décor or other aspects—interferes with the reading of the object.

A case study of a collection of mousetraps (Gundersen, 2013) described a categorisation of different construction principles with different ethical consequences, while this paper presents a case in the case study (Yin, 2009) that scrutinize one specific construction principle, the stroke design (Figure 1). Throughout human history, people have tried to combat mice, which have been regarded as a nuisance. Much time and energy has been devoted to these efforts, as evidenced by the wide variety of traps and patents developed for this purpose.

## 2 INFLUENCES ON PRODUCT DESIGN

In this article, it has been made a review of the development of a type of mousetrap from the time it was patented to the present day. The principal mousetrap construction solution is called 'stroke'. Does its evolution reflect aspects of the general social development or only product development in design, materials and ergonomics? If there are social influences, how are they visualised in the design, and can expressions of certain social beliefs be found? If such relationships exist, what impact do they have for teaching design students? This study addresses two different but related issues: first, the technological, ergonomic and material aspects of the development of this type of mousetrap construction, and second, the social and cultural norms involved. Is there a point at which product development becomes more based on the desire to distance oneself from death than, for example, ergonomic advantages for the user? In this article, the user is defined as the person who uses the mousetrap to get rid of mice.

### 2.1 Social conventions and values in design practice

There is a need to explore the influence of the development of society on approaches to product development and design solutions. It is important for students to experience and observe how social conventions influence design. What values do designers put into their designs?

### 2.1 Design students ability to analyse social values and change of norms

Design students need to gain insight into the social era in which they live and the ability to analyse how social values and norms change. Such an understanding will enable them to better practice their profession. Along with an ethical consciousness, awareness of social and cultural norms is highly important (Hopp & Stephan, 2012). The evolution and changing of these norms will always have a certain impact upon the design process (Monö, 1997). Given this background, this study aimed to answer the following research questions: How are immaterial values reflected in mousetraps?

## 3 METHOD: A CASE WITHIN A CASE STUDY

An earlier case study of mousetraps identified 11 principle solutions (Gundersen, 2013). This study is continue the study by exploring a case within the case study (Yin, 2009). The well-known stroke solution was patented around year 1900. This design is the classical mousetrap, based on this principles (Tjalve, 1976) but undergoing constant evolution. This solution has used a diversity of materials and produce differing levels of ease of use due to technological progress.

The trap studied is deadly. The most basic ethical dilemma in the world of mousetraps (and all traps in general) is whether to make or use a trap that kills or lets mice live. This particular issue is not discussed here but was addressed by earlier study (Gundersen, 2013).

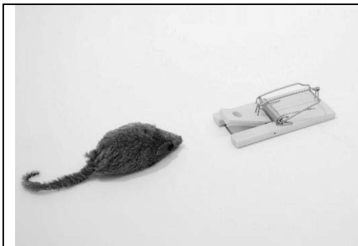
Other questions that can be raised when discussing this principal solution include the technological level in the manufacturing. From a use of simple materials and production methods in early models to highly advanced technology and manufacturing techniques in the latest examples, ergonomics has a persistent concern (Vavik & Øritsland, 1999).

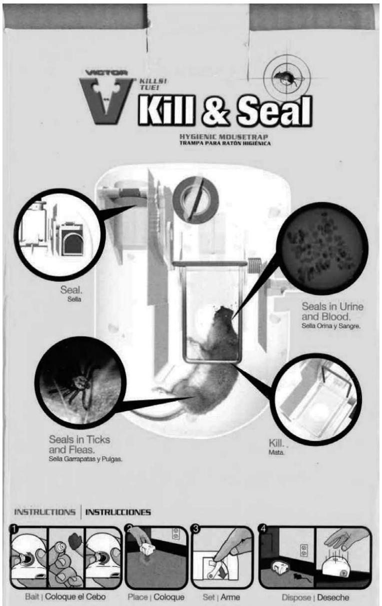
This review was designed to show the different evolutionary steps in mousetrap models in order to answer the research questions for pedagogical purposes. From among the many variations in materials and function in examples of the chosen trap design, some distinct models based on the principle of death through stroke were selected.

## 4 FINDINGS: FIVE DISTINCT STEPS IN THE EVOLUTION OF THE MOUSETRAP

This case study of mousetraps focuses on what has been a principle solution of mousetrap construction from the first patented trap in the early 1900s to the most recent models: a stroke against the neck of mice. The documentation shows how the objects express the product evolution. Visual and material differences and elements that could have some social significance are pointed out.

*Table 1. Five versions of the mousetrap stroke design*

| | | |
|---|---|---|
|  |  | Stroke. Version 1. England<br>Patented in 1894 by William C. Hooker.<br>To empty the trap, the user must lift the clamp. The user barely avoids touching the dead body. |
|  |  | Stroke. Version 2.<br>Norway<br>In this model, there is no danger of contact with the dead animal, although the user's hands are not far from the body. The user places one hand on the lever on the top to lift the clamp. |
|  |  | Stroke. Version 3<br>Sweden<br>This trap gives the user a longer distance from the dead animal. Pulling the lever at the rear releases part of the trap, and the dead animal falls out. |
|  |  | Stroke. Version 4.<br>USA<br>The dead animal is not visible to the user. Pulling the lever behind the 'house' loosens the dead animal and allows it to be removed a long distance from the user's hand. |
|  |  | Stroke. Version 5<br>USA<br>The animal must go inside the trap to get to the bait. When the trap strikes, it is sealed. The user will not have visual or any other contact with the dead animal. The trap is discarded after use. |




Kill & Seal packaging:

‘Even after they’re caught, mice don’t stop threatening your family and pets:

A mouse caught in a traditional trap releases bodily fluids that could potentially spread diseases like Salmonella and even trigger asthma attacks.

Mice commonly carry parasites like fleas and ticks that can spread serious illnesses, including Lyme disease. These parasites will jump from a dead mouse to a new host, like kids and pets.

Victor’s Kill N’ Seal mousetrap seals in the mouse a parasites to help protect your family and pets from these hazards.’

*Figure 2. Kill & Seal packaging for version 5*

## 5 DISCUSSION: WHAT HAS INFLUENCED THE PRODUCT DEVELOPMENT OF THE MOUSETRAP?

This case study of mousetraps explored one principle solution of mousetrap construction from the early 1900s to today—a stroke against the neck of mice—and documented how its evolution has been expressed in objects. Next, the paper discusses how visual and material differences arise in technology over time and how social and cultural norms influence this evolution.

### 5.1 Cultural norms related to fundamental issues

The paper will discuss whether the evolution of the mousetrap has been influenced more by pragmatic and ergonomic concerns or by social developments concerning how cultures approach questions related to fundamental issues, such as death.

This study next considers how the development of the mousetrap relates to time and traditions. The first version of the mousetrap was influenced not by ergonomics but by pure function (Table 1, version1). Eventually, ergonomics and function were integrated in new ways, offering greater usability (Table 1, version 2) and the ability to handle the mousetrap without being exposed to danger (Table 1, version 5.1). Gradually, the mousetrap evolved with the use of new and more advanced materials, such as a combination of plastic with traditional materials. The mousetrap also used metal and more advanced methods and materials, which required punching, bending and other, more complex production engineering approaches.

In addition, this study shows how distance between the user and the dead animal has evolved over time, increasing in each stage of development (Table 1, versions 1–5). The construction of the most recent version of the mousetrap allows the user to avoid handling the dead animal. When the mousetrap is activated, it is sealed at the same time, as explained in the Kill & Seal packaging (Figure 2). This mousetrap design can be seen as an expression of the contemporary aversion to death (Becker, 1975). This relationship demonstrates that social and cultural norms might have a greater impact on product development than purely ergonomic, functionality and material factors. This product development is visualised to simplify and clarify the relationship between technology and social norms (Figure 3).

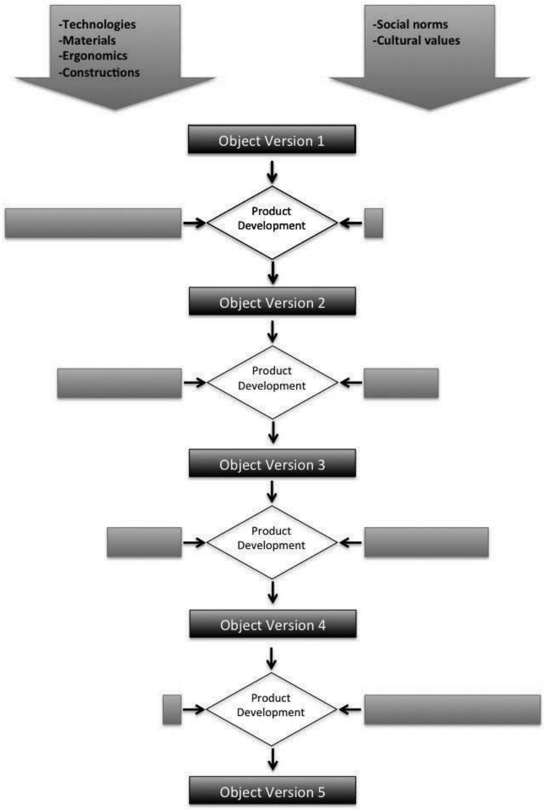



*Figure 3. Model of the five versions of the mousetrap stroke design (Table 1) which shows the relation between technology and social norms and the extent to which they influence product development*

## 5.2 Cultural denial expressed in product design

The relationship people have to death has changed in Norwegian culture, according to studies by the Norwegian Folk Museum (Seim, 2012). These researchers report that, around 1900 in Norway, post-mortem portraits were usually taken of the dead, but this tradition disappeared in the middle of that century. They explain how this tendency to hide the dead has evolved gradually until that today, one does not see the deceased at all, only a white coffin during the funeral. Mousetrap design, too, has attempted to avoid the discomfort of associated with direct visual, exposure to death. It is evident that ergonomics and usability are no longer the highest priorities in mousetrap design but, rather, avoiding close contact with a dead animal, both physical and visual (Table 1, Version 2-5). Cultural diversity also affects product design and it's the relationship to death, for example, the culture in Ghana treats death differently  which influence coffin making (Secretan, 2000). Death is more a part of everyday life and is not something to hide; coffin-makers exhibit their wares on the street next to car accessory stores. In contrast, during the past one hundred years, Western culture has seen a movement to avoid exposure to death (Becker, 1975). Ernst Becker states that civilisations adopt symbolic defence mechanisms against the certainty of our mortality. The most recent mousetrap model (Table 1, version 5) can be seen as a sign (Monö, 1997) of discomfort at seeing a dead animal; in this model, social norms have outweighed more practical development. The visual packaging displaces and denies of death. In addition, the complex production method requires expensive tools, much non-biodegradable material and an intricate assembly work so that the product cannot compensate for the energy put into its use.

### 5.3 Impact for design students

By presenting and analysing the history of the mousetrap and relevant theory, this study has presents relevance for design students. The development of the mousetrap serves as an example of how social attitudes and cultural values change and have a major influence on designers. It is important for students to be aware of such issues. They must be able to reflect on these topics in order to function optimally in their own contemporary culture. Doing so will enable them to take responsibility for influencing their own culture and to reflect on the market and social awareness. The market should demand sustainable products, and Papánek argues that social responsibility is central to designers' profession (Papanek, 1971). At the same time, designers must deal with the world as it is and should consider market needs.

## 6 CONCLUSION

The relations of complex issues to simple, everyday objects have been demonstrated through specific, typical and historical examples of this mousetrap construction and a visual illustration of its development for over for more than 100 years. The aim of the study was to contribute to the pedagogy for design related to social development by presenting and discussing technical-solution and design evolution. It has been argued that ideally designers should assume social responsibility (Papanek, 1971). In this context, this case study shows how social norms outweigh technical and ergonomic considerations in product development. The production of a single mousetrap—a sealed coffin for only one mouse—with advanced manufacturing and large quantities of many different materials demonstrates that, in this case, certain social and cultural norms were the main influences on the design process.

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# DESIGN REASONING PATTERNS IN NPD EDUCATION DESIGN

**Tero JUUTI[1], Timo LEHTONEN[1], Kaisu RÄTTYÄ[2], Nillo HALONEN[1], Mikko VANHATALO[1], Päivi KUJANSUU[3]**
[1]Tampere University of Technology, Machine and Production Engineering
[2]University of Eastern Finland
[3]University of Tampere, Finland

**ABSTRACT**
Our motivation is to introduce how design reasoning patterns are used in the Integrated Product and Product Design study module design. We use three education design questions to demonstrate what the design reasoning patterns are. The first question focuses on the interplay of subject matter and pedagogical content knowledge. The second question focuses how new scientific findings in research projects impact on course contents. The third question focuses on the many aspects and stakeholders making decisions on the curriculum. This research follows educational design research methodology. We use data from our six teaching development projects, most of them reported in earlier E&PDE conferences, the reports and related research. The map is updated based on the research project results, case summaries from the IPPD courses from our experiments and observations during the years 1995-2014.
The design reasoning patterns show how the simulation game creates common point of reference to the students and to the teacher. It is an example how increased pedagogical content knowledge effects on student learning and on teaching effort. For the second question we are able to find reasoning pattern that shows the “Teacher as researcher” –approach is working and how the latest research results can be used quickly in education.  The design reasoning pattern for the third question reveals that the background and work life experience of the professor and his predecessors played a key role on the curriculum design and that there are many stakeholders with different needs having effect on the curriculum design.
Our experience is that design reasoning patterns are a useful tool to make subject matter knowledge and pedagogical content knowledge explicit and develop course content and implementation. The map creates common ground for people from different functional areas of university organization to develop curriculum together.

*Keywords: Design reasoning pattern, cause-effect map, curriculum design, course design, teacher knowledge domains, subject matter knowledge, pedagogical content knowledge*

## 1 MOTIVATION

Could the course development and curriculum design be more efficient, less time consuming and result in better performance in learning with less effort from student and from teacher point of view? The goal of this paper is to show what design reasoning patterns are and how these patterns, visualized as a map, ease the curriculum development, course development and implementation.
Engineers, designers and project teams are able to create systems and artefacts more and more efficiently. Global companies use platform organizations and module development teams to support efficient design by re-use. The organizational aspect and the components developed earlier are required but this does not suffice. Efficient design by re-use requires understanding of design reasoning of the originating team by the re-using team. This is not currently supported by PDM/PLM systems [1]. Typically some changes in design are needed to fulfil the project goals. Therefore it is very important to know the originating team assumptions and constraints for the re-usable component. Otherwise too much redesign is needed thus creating waste work and losing the efficiency. The role of explicit design reasoning patterns and the routines to capture and share them is the key to efficient

product development. The research in Japan [2] and our recent cases [3] in companies' highlights how it plays major role for achieving the efficiency and faster time to profit.

We have used design reasoning mapping successfully in multiple new product development cases in industry. Curriculum design, course design and implementation with reasonable development steps and change control is a similar design challenge for teachers as the creation of technical system for engineering team. Now we apply the same approach in education design context and use concrete examples in the Integrated Product and Production Design education design.

In this research the **design reasoning pattern** refers to knowledge on the reasons why the product is as it is. This is typically tacit knowledge by nature. For example we could get all the design data from VAG group and investigate the product architecture and structure of Audi A6. We can see all the components and sub-assemblies in the 3D-CAD but the documentation explaining why the architecture is such, why those particular technologies and components were chosen is missing. To our knowledge the current design and engineering processes in industry require documents for the manufacturing as the outcome. The path how these solutions were conceived and chosen is not requested. The information why the designers and engineers ended up with these particular choices is not required nor managed. The quality of the design can be improved and the design management can be more effective with the visualized design reasoning patterns.

## 2 RESEARCH AND EDUCATION CONTEXT

IPPD Research team works very closely with the industry and most of the research is done with companies. This research is an exception and it is done together with the university students. Our education context is higher education, from first year to fourth year students aiming for Master of Science in product development. The IPPD study module consists of four courses and the basic information is presented in Table 1.

*Table 1. The IPPD study module courses*

| | | | | | Learning event types | | |
|---|---|---|---|---|---|---|---|
| Course | Semester | N:o students | Credit points | Planned learning events | Lectures % | Personal work % | Team-work % |
| Product Development | 2 | 100 | 4 | 13 | 50 | 50 | 0 |
| Modularization | 6 | 50-60 | 5 | 12 | 95 | 0 | 5 |
| NPD Project management | 6 | 30-40 | 5 | 7 | 10 | 10-20 | 70-80 |
| CDIO (Candidate level) | 7 | 30-40 | 4 | 4 | 10 | 10-20 | 70-80 |

Table 1 covers the courses within the scope of this study. One planned learning event can be lecture, facilitated group work or e.g. simulation game session. The learning events have a planned sequence. The percentages show the emphasis between different learning event types.

## 3 RESEARCH APPROACH AND STEPS

This research follows educational design research methodology (EDRM) [4]. We use data from our six teaching development projects, most of them reported in earlier E&PDE conferences, the reports and related research. The map is updated based on the research project results, case summaries from the IPPD courses from our experiments and observations during the years 1995-2014. We also use research on teacher knowledge domains and university wide study on the current state and challenges in university education. This data is also integrated to the map.

We use following steps for this modelling activity: 1) Identify elements based on the final deliverable. 2) Go to the detail level needed to be able to map out the dependencies. 3) Remove hierarchy to simplify the model. The model is based on cause-effect connections, not based on hierarchy and classification. 4) Identify dependencies between elements. 5) Validate the map and make corrections. 6) Identify design reasoning patterns.

In this kind of work the challenge is to find out what is the appropriate level of detail. If the elements are on too abstract level they look black boxes to us. The problem is that we don't know what happens

inside the black box. If the elements are on too detail level the validation is very laborious. It is more difficult to find out the relevant elements for the design reasoning patterns with too many details.
The modelling is also a learning activity for our research team. Some of the decisions regarding course development and study module development have been conscious and some based on tacit knowledge. According to Putnam et al. [5], the subject matter knowledge consists of the course content and subject matter i.e. what to teach. The pedagogical content knowledge consists of methods, tools, representations, stories, metaphors, analogies etc. on how to teach certain subject matter for certain students in particular learning event [6].

## 4 IPPD EDUCATION DESIGN REASONING PATTERNS

The modelling results in lot of elements and it requires printed A0-size map to be able to see and read the elements. The map size forced us to present only some of the design reasoning patterns here. The map is done with CMAP-tool and is available in Research Gate [7]. We use three education design questions to fulfil our goals and to demonstrate what the design reasoning patterns could be. First question focuses on the interplay of subject matter and pedagogical content knowledge. The second question focuses how new scientific findings in research projects impact on course contents. The third question focuses on the many aspects and stakeholders making decisions on the curriculum. The **text is on bold** when it is part of the design reasoning pattern and visible in the map.

### 4.1 Why to use simulation games during early phases of the course?

This is an example of the subject matter and pedagogical interplay. **Problem based learning was familiar approach** for the teachers since 1994 and different kind of concrete design tasks were used as simulations for the students in other courses to some extent. The first NPD simulation game experiences were from industry during 2000-2002[8, 9]. The learning results were promising [10] and the same simulation was used also for the students in Modularisation course. It was used in second last lecture. The students learned partially the design re-use phenomena but most of the focus was in building blocks and in the details of the construction kit. It gave the basic idea of platforms but it **was not integrated** to the subject matter. After some years when the research group had acquired **better understanding on the Module Systems**, the simulation was reinvented with the support of external simulation game experts. It is based on **simple construction kit**, easier to assemble and the **Kolb's learning circle [11]** with concept mapping was integrated to the simulation game. The learning results were much improved due to the **constructivist** approach **with concept mapping** and **hands on learning**. During 2013 the subject matter **sequence** was altered. The first lecture is introduction to Module Systems and the second learning event is implemented with simulation game.
The student background and experience **heterogeneity** has increased during 2002-2014. There are more and more students that **lack concrete experience on technical systems**, how they work and how they are repaired. How could they have any **reasonable mental models to** learn the challenges in designing such systems? The simulation game enables **common point of reference** to the students and to the teacher. Later during the course learning events the teacher can refer any occasion during the simulation game, reminding of the concrete challenge or situation **and interweave it to the subject matter** at hand, such as how to design interfaces for the Module System for module interchangeability. The recent learning results have even improved due to these changes. This shows how increased pedagogical content knowledge can reduce teacher work effort and enhance student learning.
Product Development course is an introduction to technical systems, different development processes and NPD project organisations. During 2013 and 2014 new simulation game was used. The key subject matter is to highlight how the number of project participants have an effect on project problem solving ability, communication ability and to the project schedule. This simulation is used after the introduction lecture. The students are divided into three groups, 10-person, 20-person and 70-person group. They are given the same design task and 15 minutes to create the solution with basic building blocks. After this we facilitate pair discussions on what was the challenge. The findings are written on the board for each group. In this point the teacher is able to assess how well the students learned the subject matter and can elaborate on the topic if needed.
Based on the student findings the teacher explains **how and why the simulation is done again**. This time there are **many changes** such as **smaller groups**, the design task is divided into **smaller steps**, concepting phase, development phase and integration phase. The most **viable concepts are chosen**

and **interface and layout drawings are documented** on the board. **Team leaders are chosen** and **communication practices** are agreed. Then the simulation is done again. This time the result is much better, the **steps are visible** and most of the students had worthwhile contribution to the design task. The reasoning pattern for this implementation is similar to the Modularisation; the **heterogeneity, lack of concrete experience on technical systems and lack of project work experience.** They **have not been in NPD project** so they cannot imagine the effect of number of people. In this case the simulation enables **common point of reference** to the students and to the teacher and it **provides motivation to study** the rest of IPPD study module.

### 4.2 How the key subject matter is chosen for NPD project management course?

In the 90's, NPD Project management was based on Critical Path Management and learning the PERT. This was mainly due to the work life experience of the professor in charge. The company specific project management manual was the starting point and one tool was covered in one lecture. The educational goals were different from current situation. Nowadays we also have more expansive and relevant set of literature, study books, journal publications and research results on new product development project management. **Ambition has also grown during the years and the needs from the industry** and from the academy, too.

The changes were based on **problem based learning (PBL)** and the project cases varied from container ships to buses and bicycles. The goal is to create plan and schedule for **new city bus and the production system**. We encourage the students to take **responsibility of the overall success** rather than optimise own grade only. The team that presents the most competitive offering, wins and they get raise on the final grade. The **success criteria's are credibility of the project plan, delivery time, cost of the bus and fulfilling the technical requirements**.

During 2010 our **research project** in this field had good **results** from the industry and software tool was prepared to manage project delivery dependencies. Gantt-chart software is used and it was capable of creating schedules. It is focused on tasks and resource management but it is poor on modelling **how new knowledge is emerging during the development project**. On year 2012 the tool, especially designed to model and manage how new knowledge is created, was taken in use. At the same time the course content was changed to emphasise "white box" project management; manage the project based on deliverables, deliverable interdependencies and tasks rather than task management and reporting that is more like "black box" project management.

The project teams had typically **90-130 tasks** in their project plans during 2007-2012 and the teams' reported some or major problems in managing the dependencies with MS Project. By nature the tool does not support iteration that often takes place in these NPD projects. Year 2013 one team had over **1100 tasks** in their plan yet reporting it was easy to manage changes, iteration, dependencies and critical path with the tool combination. Year 2014 the best team had gone **over 2000 tasks** in the Gantt-chart without problems. This is **major leap for the project management efficiency and accuracy**.

Since 2009 the project team had to make agreement on their **operative practises**. The teams created such a document as it was requested but it had no impact on their actual working habits. On year 2014 the fifth learning event on the course is dedicated on operative routines and learning in the projects. This time the project teams were using facilitation method and templates created by Kopra [12]. Each team was able to identify what project routines to improve and they also created practical actions for the next week to improve the chosen routines.

The design reasoning patterns in this case originate partly from the **new subject matter knowledge found and created by the research group**. In our case we have **highly integrated education and research team** where the same persons do both research and education and the "teacher as researcher"-approach [13] is working well. The **competition approach is used** as this **is the reality in projecting business**, only the best gets the deal.

### 4.3 Why the IPPD Study Module consists of these courses with these subject matters?

The modelling is based on Culture Historic Activity Theory [14] and when applied with organisations and institutes we need to consider what has happened earlier to understand what the situation right now is. We continued expanding the model by considering all influencing activity systems to the curriculum design. In this paper we elaborate the key activity systems starting from Ministry of

Education to the student and course level activity system. The decision making takes place in these activity systems based on different goals and policies. The decisions made on Ministry has effect on university, faculty, laboratory, professor and researcher via several routes.

The Ministry of Education and Culture provides certain amount of money within education policy agreed in the parliament. The policy guides students to graduate within 4 years, sets constraint on how many **starting places are opened** per university and curriculum etc. University gets funding mainly based on number of graduates thus setting motivation for the activity systems beneath to adjust the goals and criteria for passing the course accordingly. On university level there are **many faculties with own curriculum consisting of partly same study modules or courses**. This creates interdependencies between the courses and also between the implementations on different years. Different faculties **change their curriculum, study modules and courses on different intervals** and the change control for single course is difficult.

On research group level activity system there is control from the above mentioned activity systems. The **industry requires competent and capable students** and this message is conveyed from university board level to faculties and laboratories. The culture and goals in these activity systems Roth et al. [14] have big influence on the course development and on the study module development and implementation. The course development and study module **development is affected by the valuation and contribution** from the professor and from the research group members. The IPPD group has **direct contacts with industry people** and open forum for industry and researchers to discuss on the product development issues.

According to Kujansuu [15] in worst case the successes in education development are not discussed at all in personal performance review with the professor. In some cases there was no time allocated or reserved on course development. On teacher activity system the findings were much more inspiring by Kujansuu [15]. The teachers were enjoying the academic freedom to choose their own focus, they had **strong personal motivation** to develop the course and to be **experts in the subject matter and in the pedagogical content knowledge**.

The design reasoning patterns show that there are many aspects on curriculum design and many stakeholders with different needs having effect on the curriculum. The curriculum design appears to be very iterative and consists of lot of **interdependencies between different decisions** needed. In addition the university as an **organisation suffers from conflicting decisions and lack of decisions** on different organisation levels. During the modelling we realised that **the background and work life experience of the professor and his predecessors played a key role on the curriculum, courses, course contents and subject matters.**

## 5 CONCLUSIONS

The design reasoning patterns provide answer to the first question by visualizing how the simulation game creates common point of reference to the students and to the teacher as well as interweaves the engineering challenges during the learning event to the subject matter. It is an example how increased pedagogical content knowledge effects on student learning and on teaching effort. For the second question we are able to find reasoning pattern that shows the “Teacher as researcher” –approach is working. The latest research results can be used quickly in education because of the knowledge is transferred within the highly integrated education and research team. The design reasoning pattern for the third question reveals that the background and work life experience of the professor and his predecessors played a key role on the curriculum and that there are many stakeholders with different needs having effect on the curriculum design.

Our experience is that design reasoning patterns are a useful tool to make pedagogical content knowledge explicit and develop course content and implementation. The map creates common ground for people from different functional areas of university organization to develop curriculum together.

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# AN EXPERIENCE-BASED APPROACH TO TEACHING PRODUCT DESIGN

**Juan JAUREGUI BECKER and Wessel WITS**
Laboratory of Design, Production and Management, University of Twente, The Netherlands

**ABSTRACT**
This paper presents a new experienced-based approach to teaching product design. The goal is to address specific issues that are difficult to teach to students effectively in a purely theoretical setting, as students need to have experienced in some way the behaviours involved in managing a product design process. The backbone of the approach is a design game that allows students to experience themselves some of the most important challenges in product design. Later during the course, the concepts of product design are taught by always referring to the specific part of the game in which that aspect was relevant.

*Keywords: Experienced-based learning, Product design process, Product development process*

## 1 INTRODUCTION

Product Design has become a standard Operations Management (OM) course in engineering, industrial design and business master programs all over the world. The course is often based on formal and well-accepted design literature (e.g. Ulrich & Eppinger [1], Pahl & Beitz [2]). Its main goal is to teach students how the design process is structured in different phases, which design tools can best be used during each phase and, finally, how human, material and time resources are organized such that the entire design process is accomplished successfully. Although the contents of such courses are neither difficult nor complex, it remains a challenge to have students understanding the concepts taught and its importance for their professional future.

In our specific case, we have provided this course for the Mechanical Engineering master program at the University of Twente for the past 5 years using as teaching method regular lectures with several case study descriptions. However, the course evaluations done by students have repeatedly shown a common problem: students perceive the course as vague and do not think its contents will be of much added value as professionals. By further analyzing this issue in panel discussions with students, it was determined that the most likely cause of this is the fact that students' experience in product design is limited to designing simple products in groups not larger than 8 people, which is one of the learning goals of our bachelor program. Therefore, as the nature of the course is rather organizational than technical, students have difficulty in empathizing with the challenges this course addresses.

With this background, in this paper we present a new experienced-based approach to teaching product design. Such an approach has been a common practice for around half a century in OM education. In fact, OM education literature reports a variety of games [3] that range from the simple 'tabletop' game [4], to the more complex system simulation Beer game [5], up to the more interactive environments such as a 'training factory' [6]. Several reasons lie behind such a massive utilization of games in OM. One is that games address specific issues that are difficult to teach to students effectively in a purely theoretical setting as students need to have experienced in some way the behaviours involved in managing a production system. This is particularly important when the course represents one student's first exposure to OM practice. For students with more experience in OM practice, games serve as confrontation mechanisms that can make them aware of their limitations by allowing them to experience the challenges a given course deals with. Doing so also aids the instructors in having students understand the mapping between challenges, learning objectives and the themes covered in the course.

This paper is largely motivated by the practical experience the authors have in teaching design subjects to students with technical backgrounds. The rationale of the approach is that students need to experience the challenges of product design in real organizations in order to be able to learn approaches for solving them. The backbone of the approach is a design game that allows students to experience themselves some of the most important challenges in product development. Later during the course, the concepts of product development are taught by always referring to the specific part of the game in which that aspect was dealt with by them. The paper is further organized in 3 more sections. Section 2 presents the characteristics of the course, the results of a panel discussion of previous course evaluations, and proposes a new teaching method based on a Product Design simulation game. Section 3 describes the details of the game as it was applied for the first time in our course. Finally, Section 4 presents the conclusions and recommendations.

## 2 THE PRODUCT DESIGN COURSE

The course Product Design supports the students in becoming a design engineer or design engineering manager. The course teaches design theory and methodology, covering amongst others the design process by Ulrich & Eppinger [1] and Pahl & Beitz [2], the FBS method [7], the usage of Design Process Units [8], specific design tools (e.g. Quality Function Deployment, Product Data Management, and Failure Mode and Effect Analysis), and it observes of the complete design process from customer needs to production planning and ramp-up. Functions central to product development projects, such as marketing, design and manufacturing, are studied. Several models of integral design are treated and compared. Furthermore, different aspects of the product life cycle are involved, for instance functional performances and makeability.

### 2.1 Former course structure

The course has been taught in former years using a combination of lectures based on several chapters of the book of Ulrich & Eppinger [1] and asking students to make small exercises based on most of the treated chapters. As a consequence, the structure of the lectures followed the structure of the book discussing the design process from planning to production ramp-up. The course taught a total of 18 themes, over a total of 28 lectures of 45 min. each.

### 2.2 Students evaluation and analysis

The course was evaluated using a qualitative research method combined with open questions, to allow students to indicate their personal and anonymous perception of the course. A fragment of summary presented by the student's evaluation board –the official body in charge of organizing student's course evaluations– reads as follows [9]:

> *"During the course a lot of different models and tools are presented, but the tools are not all applied within the course. Therefore students experience little depth which is expected based on other own experiences with other master courses. A side effect of this is that student's experience that they learned a lot of stuff they still know nothing about. They know of the existence of the models and tools, but not when to use them or how to use them. To gain this insight more experience with the models and tools is needed. The goal of exercises was not really clear to a large group of students. A number of students mentioned that they would prefer fewer exercises with more depth. Students also mention they would like to apply tools more on the design of a real product instead of analyzing existing products. The name of the course indicated the focus would be more on the design of a new product.…"*

After analyzing this summary and the results of the qualitative research study [9], the main conclusion that was drawn was that students do clearly not perceive the goal of the subject. Rather than designing one product, the subject's goal is to teach how to organize the process of designing any product and determining which tools and organizational forms are available for doing so.

### 2.3 New course structure

Given the previously described issues, the teaching method of this subject was reformulated. The goal was to develop new didactics that would enhance how the contents are conveyed to the students. Therefore, only the teaching methods were modified, and not the contents. The new subject structure makes use of two types of teaching methods:

1. An experience game: a new Product Development Process (PDP) game was designed to reinforce learning of the organizational aspects of the PDP. The goal of the designed game is to have students experience a chaotic PDP.
2. Instruction lectures: lectures that combine teaching theory with practical workshops in which

students have to apply the newly learned contents to solve a given problem. The instruction lectures refer to those parts of the game the learning material is aimed at and the exercises are about organizing the design process of one same product.

This paper aims at describing the experience game.

## 3 THE PRODUCT DESIGN GAME

The game was developed following the education design game framework proposed in [10]. This model, shown in Figure 1, addresses that educational games should include:

1. An input set consisting of a description of the role of the players, the role of the game's umpire, and the eventual devices and hardware required to do the game.
2. A process description describing the initial conditions, the phases and the rules of the game.
3. An output set describing the expected results of the problem solving task regarded in the game and the expected insights to be learned by the game players.

The following subsections refer to the most important parts of this structure to describe the game. Some issues are omitted because of space constrains.

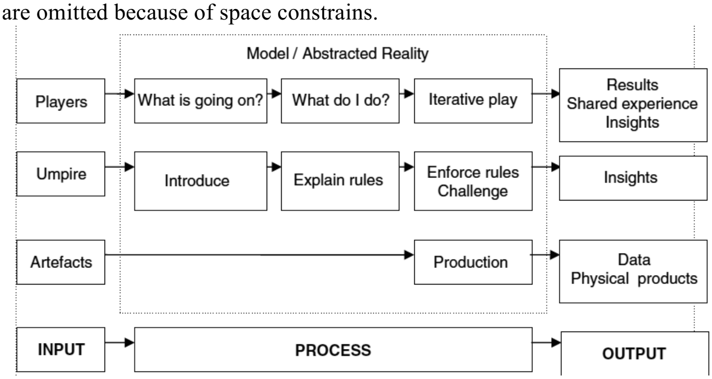


*Figure 1. Framework for development learning games in Operations Management [10]*

### 3.1 Learning Objectives

The learning objectives of this game are twofold. On the one hand, it seeks to enable students in undergoing a complex ideation process, experiencing the differences in exploring a problem space and a solution space, and understand the differences of undergoing a convergence and a divergence process in a large team. On the other hand, it strives for having students experience the chaos and stress of a real-life complex product design process by confronting them with issues as fixed decision gates and working in light and heavy weight organization structures.

### 3.2 General description

The new product design game we have developed consists of simulating different aspects of a complex PDP. For its first implementation, and considering the students have a background on mechanical engineering and mechatronics, the game simulates the PDP of a mechatronic anti-earth quake system for skyscrapers in seismic areas. The game assumes that there is one company developing such systems and that the company has 4 projects that have to be developed concurrently. Each project deals with one anti-earthquake system for a given building in one of four cities in different places around the world, namely, Delhi, Manila, San Francisco and Tokyo. During the game, students have to work in teams to produce one concept design for each city. As the game progresses, students experience how is it like to work with different types of team configurations (as heavy-weight, light-weight and functional teams), to do convergent and divergent design, and to undergo synthesis and analysis processes.

### 3.3 Initial condition

The initial condition of this game is given to each student team in the form of a design brief. The design brief provides a small technical description of one building, its geographic location and the expected earthquake damping ratio the system should achieve. The four buildings provided for this game are existing building in Delhi (Civic Center), Manila (Roxas Boulevard), San Francisco

(Transamerica Pyramid) and Tokyo (Sunshine 60). Therefore, students can use internet to search for relevant information about those building if they deem required. Another initial condition of the game is the level of awareness students have on its learning objectives as they are not told that one of the goals is to have them experience a chaotic situation with tight deadlines.

Students were also provided with a document template indicating the information they had to submit by the end of the game. The template required students to have the follow information:

- Short summary of proposed system, indicating the main characteristics of the system.
- Sketch of the solution indicating the configuration of the solution principle in relation to the building.
- Description of the main Key Performance Indicators (KPIs) of their solution proposal: installation cost, operations costs, detail design time, installation and manufacturing time of system, reliability measure.

### 3.4 Team configuration

The game was designed for 40 students. Four teams of 10 students each were defined. Each member of each team got two types of roles assigned. The first type of role varied between being in charge of *setting up requirements* or being in charge of *proposing concept solutions*. The second type of role made distinctions between departments the players belonged to. Table 1 describes the 5 departments considered in the game and the specifications of the roles attributed to them. In conclusion, each team dealing with one city had two students assigned to each department, initially one being in charge of setting up requirements and the other one in charge of proposing concept solutions.

*Table 1. Roles of the game*

| | |
|---|---|
| **Automation department** | Determine the configuration of the mechatronic system.<br>Determine sensors (#, types and positions), actuators and control. |
| **Mechanics department** | Design the mechanisms in charge of damping the building movements.<br>Determine the dynamics and kinematics characteristics of the designed system. |
| **Construction department** | Determine the dynamics and kinematics characteristics of the building.<br>Determine the technical characteristics of the installation of the system in the building. |
| **Manufacturing logistics department** | Determine the logistics for making the systems and installing in on location. |
| **Project management department** | In charge of project milestone evaluation.<br>Steer the PDP process.<br>Enable communication between departments.<br>Document partial solutions.<br>Calculate KPIs: installation cost, operational cost, detailed design time, building time, reliability. |

### 3.5 Rounds and rules

The game is structured in four rounds, each one corresponding to one phase of the product design process. Each round deals with a different sub-problem solving task and uses different gaming rules. Furthermore, time schedules were kept tight within their limits. In fact, the game time count down was projected on the white board. The phases have been organized such that the divergence and convergence design activities occurred cyclically.

#### *3.5.1 Round 1, planning*

For this round the students were divided into two groups of twenty each. One group gathered all students with the role type *setting-up requirements*, and the other gathered all students with the role type *proposing concept solutions*. Therefore, each group had students belonging to all departments and to all four cities. The requirements group was assigned the task of determining requirements of such a mechatronic system (the problem space exploration), while the concept proposal group was assigned the task of exploring possible working principles (the solution space exploration). Each individual member was expected to provide requirements or concept solution proposals from the perspective of the department she/he belonged to. Students were allowed to use internet resources to investigate both problem descriptions and solution principles. Communication between both groups was not allowed during this round. The total time for completing this round was 25 minutes. The activity had a divergent nature in both the search of important requirements and the search of possible concept solutions.

#### 3.5.2 Round 2, conceptual design

For this round, the students were organized in 4 project teams. Each project team gathered people working on the same city. The aim of this round was to force the quick convergence towards one conceptual solution by clashing the half of the project team that investigated requirements with the other half that investigated concept solutions. After doing so, each team had to decompose the designed concept into 4 subsystems for each department to further detail in the next round. The total time for completing the task of this round was 20 minutes.

#### 3.5.3 Round 3, layout design

This round had the goal of further detailing the already chosen conceptual solution. The playing room was organized as shown in Figure 3. Here, each department's location gathered students from all four project teams. The goal of doing so was to enhance interdepartmental communication. Furthermore, students of each department were allowed to discuss their progress with the managers for 5 minutes every 10 minutes at their city project table. As an additional challenge, through the project management team updated customer requirements (e.g. building height, earthquake damping ratio) were brought into the game. The managers were free to distribute this information as they saw fit. This round of the game lasted 40 minutes in total.

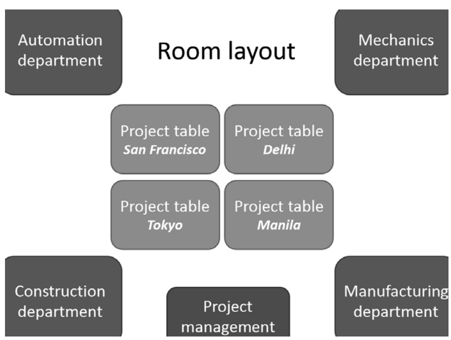


*Figure 2. Departmental layout for round 3 of game*

#### 3.5.4 Round 4, documentation

In this round the resulting sub systems had to be integrated into one final solution. Also, each team had to fill-in a template describing the characteristics of their proposed solution. The game ended by submitting this template.

### 3.6 Reflection

After finishing the game, students were asked to reflect upon their experiences in terms of what went well and what went wrong. Interestingly not all students were aware of the updated customer requirements. Once this was done, a group discussion was initiated. After gathering most of the students' perceptions, it was revealed to them that the goal of this game was to have them experience in a short time span some of the major organizational challenges of the PDP. Next, a traditional lecture on project management was provided in which constant references to the game experiences were made.

### 3.7 Evaluation process

As a final evaluation of the subject, students were required to design a PDP for the fictional company developing anti-earthquake systems. Firstly, they were asked to detail the different decision-making processes and determine which tools can be used best for dealing with them. The results had to be presented in a structured network. Furthermore, they had to include which information is input and which information is output for each design tool. Secondly, they had to describe how they would organize their PDP. More specifically, to discuss the organization in terms of teams and personnel, types of team structures, types of project management approach (e.g. agile, lean) and finally to elaborate on how they would manage decision gates such that uncertainty is minimized, documentation is assured and interdepartmental communication works properly.

## 4 CONCLUSIONS

This paper presented a new experience-based approach to teach a Product Design course. After analyzing the implemented approach in panel discussions with students three main conclusions can be drawn. Firstly, students were now able to comprehend the challenges of product development from an organizational point of view. More specifically, the role of communication among interdisciplinary team members distributed over several departments, the importance of documentation to both support communicating technical issues and fix current status of the design process, and finally, the need to manage design uncertainty during the different phases of the PDP and among interdisciplinary teams. Secondly, students showed comprehension on why different products require different combinations of tools arranged in specific ways through the PDP. More specifically, making the distinction that different combinations of toolsets are required for different types of products, as for example a one-off product, a new platform technology and a new product version. Thirdly, gained insights in the implications that implementing certain design tools have on the product development process, further than the principal functionality the tool has. For example, students recognize that the added value of a House of Quality (QFD) for an organization goes far beyond just having it. In reality, it is the process of making it where companies get aware of their capabilities and its relation to their market needs.

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# SHARED MEMORY IN DESIGN COMPLEXITY

**Nenad PAVEL**[1] **and Arild BERG**[1,2]
[1]Oslo and Akershus University College of Applied Sciences
[2]Alvar Aalto University, Helsinki

**ABSTRACT**
This paper discusses the idea of how collaborative learning might help designers with the rapid learning required in the increasingly complex environments they work in. It has been proposed that innovation that drive technological advancement happens through evolutionary variation of the existing knowledge. The relevance of such an approach is that rapid learning is essential for a designer in a technological environment that is increasingly complex. The goal of the systemic design approach that addresses rapid learning is to facilitate mapping of a problem context that can include findings outside the designer's field of competence. A rapid learning process emphasizes self-directed learning. There is a need for more knowledge on how designers could learn from their collaborators to gain project relevant tacit knowledge. The method chosen to address this was case study of a student project. The case study showed how a group of students was collaborating with an external partner, a bank savings foundation, learning rapidly through mind mapping system program. The conclusion of the study was that memes in a creative design process are connected to learning outcomes related to communication and empathy. The identified cognitive qualities of empathy relevant for the design process were multi-functionality, symbolism and brand recognition. The emotional qualities of empathy that were identified were corporate values that might contribute to corporate social responsibility and social interaction. The compassionate qualities of empathy were mutual benefit and positive consequences in society.

*Keywords: Creativity, flow, design collaboration, learning outcomes in product design, e-tool*

## 1 INTRODUCTION: CONCEPTS FROM CONTEXTUAL RESOURCE

According to the psychologist Mihaly Csikszentmihalyi existing knowledge is constituted of traditions called memes; new concepts that has been implemented into society [1]. He claims that the memes accessibility is directly connected to the level of creativity in a society. He proposes that innovation that drive technological advancement happens through evolutionary variation of the existing knowledge. In this perspective knowledge accumulation and knowledge transfer can drive technological innovation forward. According to Nassim Taleb [2] it is too often considered that innovation emerges through a planned process of systematic research and that in reality a new practice emerges from randomness of active tinkering such as creative experiments in the design process [3]. Thus a design competence is to systematically test products through trial and error to contribute to incremental innovation. Similar ideas can be found from Steven Johnson who claims that historical records have overestimated big break through innovators as the key source for innovation; innovation more often happen gradually [4]. Theories of radical innovation tend to isolate the innovator from their context, their habitat, their culture and contextual knowledge streams. Johnson claims that these theories don't recognize the contextual resource availability and co-innovators needed in the process of operationalisation of a creative idea. This study thus aims to explore contextual relevance for emerging concepts in design practice in a complex and technological oriented practice.

### 1.1 Background: the incubation phase of a creative process

Concept emergence can be identified in the incubation phase of a creative process [5]. Incubation is a process that happens in each individual [6]. In that respect it is a designer's creative role to generate and explore concepts. That presumes that designer has to master design aspects of a given project fast and to learn rapidly about relevant situations [7]. Rapid learning process and adaptive experience are both addressed as part of a complex, systemic design approach. This is relevant in this study because rapid learning is essential to work as a designer in a technological environment that is increasingly complex [8]. The other important aspect of this research is relevant for design education. In perspective of this article designers need to be enabled to lifelong learning and self-efficacy, through active learning and failure through facilitation of adaptive experiences [9]. The article explores how designers can speed up and systematize this process.

### 1.2 A systemic design approach

The goal of the systemic design approach is to facilitate mapping of a problem context that can bare findings outside designer's field of competence which allows working in a complex setting [10, 11]. The context is researched through the whole design process but learned at the very beginning in design research. Designers use various process methods to discover these findings from their clients, users and expert informants. It can be enough to collect and map the findings in order to understand a problem context [12]. However it would be ideal if designers could possess clients, users and expert informant's tacit knowledge or memes [1]. That could enable deeper insights and generation of more credible concepts. These insights are collected by designers in a process of 'empathizing' with their subjects.

Nussbaum uses the expression *deep immersion* into a user problem or world [13], described as time devoted only for observing, learning and understanding user perspective. In practice this is the purposely uninterrupted time spent on gathering impressions from the field as well as mapping user environment and activities. This means designers have to experience a user world instead of only understanding it. According to controlled studies in autism by Rogers et.al. [14] there are three types of empathy: cognitive, emotional and compassionate.

Emotional and compassionate empathy are relevant issues in inclusive design approaches that rely on the motto *see user, hear user, be user*. A method to explore the limitations of a product or a system are through such empathy tools [15]. One example is eyewear that limits the eyesight of a wearer so that it's possible to experience the lack of seeing ability while using a product or a system. These tools encourage designers to go towards emotional empathy as they do not only understand but experience the limitations of physically disabled people. In service design [7] the goal is to enable 'Actors' to be involved, engaged and devoted to implementation of new concepts. This encourages designers to search for meaning for the actors, motivating them through the ownership of an idea and the implementation process. In this context designer is not a provider of an idea but a one of the team members that facilitates processes and takes responsibility for the outcome. Designers are encouraged to get personally involved in this process by being neutral and relating to each actor involved equally through compassionate empathy. The research question was how designers could learn from their collaborators to gain project relevant knowledge through empathic collaboration and communication.

## 2 METHOD: CASE STUDY OF DESIGN FOR A BANK FOUNDATION

The method chosen was case study of a student project for a bank foundation [16, 17]. This approach included participatory observation as a teacher, archival records and interviews. It also relied on literature studies.

### 2.1 Mindmeister mind mapping

The case study explored how a group of students was collaborating with an external partner using a mind mapping system program called Mindmeister. They mind mapped their research findings and drew connections between them. Collaboration happened both in reality and virtually as users and expert informants were taking part in mind mapping collaboration. Mindmeister is a useful research tool as it stores each version of the document that all collaborators make in a timeline. This makes it possible to see when and what data is stored as well as what is removed from the document revealing design and collaboration process through time.

### 2.2 Analysis of communication: cognitive, emotional and compassionate empathy

Csikszentmihalyi's memes are not only about to be accessible for everybody but strategically streamed through a flow of knowledge transferred and shared between participants. According to Jones et. al. [18] networked learning is a process of developing and maintaining connections with people and information, and communicating in such a way so as to support one another's learning. Networked learning theory has been revitalized in the last decade because of a major adoption of social media through communication technologies. One central term in this context is connections and communication through empathy. According to Rogers et al. [14] there are three types of empathy: cognitive, emotional and compassionate. These terms are used in the analysis, to select quotes that give a deeper practical understanding of this topic in an educational context of design, where the aim is to develop theory through case study research [17]. What relevant issues are identified in a student design project in a real life context?

## 3 PROCESS FINDINGS: DIGITAL, MATERIAL AND IMMATERIAL

In the student project of making a gift product for a bank foundation students were very motivated and adopted the Mindmeister tool easily: *Most of us felt natural to mindmap and found wanting to use it afterwards in other projects'*. They described how they were experiencing more control over the project, were accumulating more knowledge and were mastering design aspects in a better way. They have also noticed that it was easier to gather facts without focus on formulation as the mind map would automatically give context to the node. This was stimulating even more data collection in itself: *'It was important to throw everything all of us knows out without thinking critically'*. Students have claimed that the tool did not demand from them to explain themselves as the other team members could build the meaning on their own from the context of the mind map. In this case, 'Mind- meister' has removed the barrier students had in trying to express themselves creating more empathic environment. Through the project, the design research findings were mind mapped and connections drawn generating new insights. However, students were experiencing difficulties dealing with the complexity of the tool: *'We have used Mindmeister mostly for the individual work and common discussions. The common file was very soon clogged and it was not good for sharing files but only overview of the project'*. They have also experienced that it was difficult to use mind mapping to communicate with the client, as they established a very formal relationship: *'Three of us have used mind mapping to categorize our concepts but that mind mapping was not shared with a client because we wanted to be professional and mind map looked pretty chaotic.'* This can imply that students have gained and shared knowledge space through mind mapping that helped the incubation phase of the process. Still, the gained knowledge seemed to have only a slight impact on concept generation. This can be because of lack of substantial knowledge students received from their informants. This can imply that rapid learning takes place on different levels and different points throughout the collaboration. Knowledge Transfer Flow as concept embodied all the learning collaboration points concerning knowledge space exploration [19] for a given project.

### 3.1 The bank savings foundation

The project was based on collaboration between 2nd and 3rd year Bachelor students. The 3rd year students should experience to be design leaders and the 2nd year students would experience being design staff in a real design project. Although there were many projects with students who worked with external parties in business, only one was chosen as a case for this study; 12 students that developed a solution for a bank foundation. This was selected as a case study because it exemplified a complex organization where both volunteers and professionals worked together. The learning outcomes generated from the study therefore might be relevant in a variety of settings.

The students began by examining the field to see what of competing products were available on the market. They examined different ways to experience that one has received support from a foundation. They mapped variations of gifts and what the other foundations did. They made a historical study that showed how and why the bank foundation wanted to promote the values of the savings bank tradition and what does it meant in the practice of the foundation. They examined further on traditional banking and bank sponsoring. They examined what it meant to be a sponsor in compared to being a bank, and why the bank foundation often was perceived solely as a bank. They tried to identify the reason for this problem. They made a survey in the field that mapped how the logo was experienced. The survey was followed by in-depth interviews to determine the requirements and needs of the gift recipient.

In this design process, much information was exchanged in both social media and in physical meetings in classrooms. The Mindmeister program was tested and was found helpful by students. The program provided an additional dimension to research that the complex dialogue between the actors was saved. Thus the teacher could also follow the dialogue and how the concepts evolved. It created an openness and transparency in the creative process that might be useful also in a creative process in work life.

This project had a collaborative value when all the subjects were discovering the design topic for the first time and thus collectively identifying their knowledge gaps. Another value was the educational setting where subjects were exploring knowledge and concept space in order to learn how to use them. In addition, the group was sufficiently big that it needed to be split in smaller groups that had to tinker and experiment with parts of the project on their own and communicate their ideas with others.

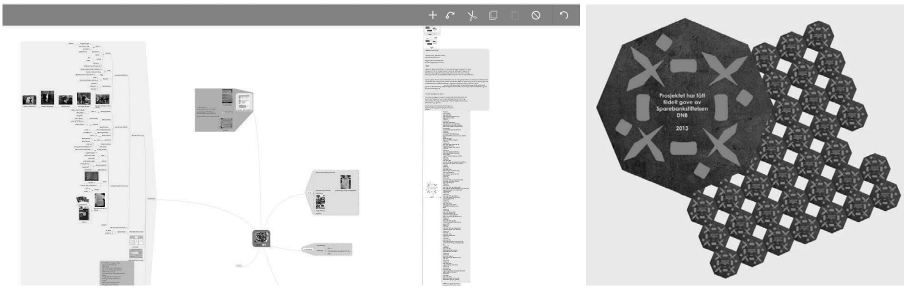


*Figure 1. Map of Mindmeister communication that led to a multifaceted gift product concept for the bank savings foundation; a concrete tile with text, flexible stickers and a digital version*

The product developed was a multifaceted solution. The concept was a product package with a logo repeated on several elements; on the material gift tiles, on a gift letter and on a waffle iron. The gift had physical, digital, social and symbolic functions where much was about creating mutual empathy between the giver and the receiver, and the community around. The qualitative analysis therefore highlighted three empathic qualities, as recommended by Rogers et al. [14]; these empathic qualities are cognitive, emotional and compassionate.

#### *3.1.1 Cognitive empathy in the design process*

Examples from the case study shows how the cognitive qualities of empathy were reflected in the project: A big "tile" in a good durable material such as concrete should be placed outside, inside, on the wall, the ground, and almost everywhere. This part of the concept would be most vital for designing gift certificates. A mini chips and label could be placed almost anywhere where you wish. Likewise, a digital network chip developed that could provide recognition effect online media. The cognitive qualities here were *multi-functionality, symbolism and recognition*.

#### *3.1.2 Emotional empathy in the design process*

Examples from the case study showed how emotional qualities of empathy were reflected in the project: Students were required to reflect the values of the Savings Bank Foundation. A waffle iron with the foundation logo was a fun and different way to show that you have received a gift. It could bring people together. The students' analysis of the logo's blue colour they associated with emotions: "By *looking at the illustration to the right, we see that the colour blue is often associated with banking and finance. Blue is a colour that is seen as loyal, loving, polite, tactful, inspirational, serious and inventive, but also as a snobbish, faithless, suspicious, conservative, lack of confidence and unstable."* The emotional qualities identified were *corporate values, social interaction, and colour associations*.

#### *3.1.3 Compassionate empathy in the design process*

Examples from the case study showed how compassionate qualities of empathy was reflected in the design project: The students wrote: *" Something we discovered while investigating other funds and foundations was that the bank foundation was especially good at explaining what they stand for and who they are on their website . They could maybe have used these web pages more as a venue to promote and appreciate the gift recipient, to put the receiver in focus?"* In the concrete tile was written within the logo *"We believe in this project. It triggers good forces."* This text was selected according to the students because the foundation gives money to good projects so that it sets in motion a ripple of good forces in society. By having a gift that says in the writing *"It triggers good forces"* several are included as being the good forces; firstly the foundation by providing money, secondly the forces of the good organization and thirdly all the good forces that comes from the public that will enjoy the gift. The gift receiver comes more into focus. The compassionate qualities here was *mutual benefit, positive consequences in society* and *faith in the individual's devotion and dedication*.

## 4 DISCUSSION: MEMES BY DIGITALISED INFORMATION

According to the psychologist Mihaly Csikszentmihalyi existing knowledge is constituted of traditions called memes [1]. By digitizing information we have chance to both adjust memes to be streamed and absorbable. Mapping the research areas, deciding on what and how to research and learning at rapid speed are design skills which are not any less important than framing a problem and exploring concepts. Design practitioners could consider setting up design sessions with the goal to learn from each other and their informants rather than solve design problems directly.

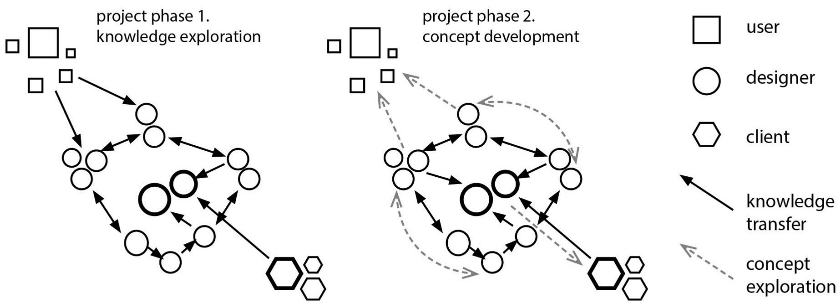


*Figure 2. A visualization of a complex knowledge transfer flow*

Mind mapping with an e-tool have some good values. The research shows how sharing knowledge exploration space had significance in both learning and generating concepts. Although concept generation can preferably be even more affected by knowledge transfer. Knowledge Transfer Flow as concept represents all the learning collaboration points concerning knowledge space exploration for a given project, as visualized (Figure 2). This flow might be inclined, facilitated and streamlined effectively with new technological and design process tools. A possible implication from the study is that approaches in design education largely can set up design sessions with the goal to learn from each other and their collaborators rather than to solve design problems directly. Further research might reveal how it can be enthused and facilitated with new technological design process tools.

## 5 CONCLUSION: COMMUNICATION BY E-TOOL

The conclusion of the study was that memes in a creative design process were not only to be accessible but had the potential to be strategically streamed by e-tools to a flow of knowledge. Learning outcomes related to this pedagogical approach includes skills of mapping the research areas, deciding on what and how to research and learning at rapid speed. The qualitative analysis in this study highlighted three empathic qualities related to this concept [14]; these empathic qualities are cognitive, emotional and compassionate. They were relevant in the design process of the study, and they might be relevant learning outcomes for bachelor students in product design. Such learning outcomes was in this study promoted by a practice oriented project, with many collaborators in a complex context. In this study, the process was supported by an e-tool that enhanced the learning process between many participants. It also documented the learning process in a transparent way.

### 5.1 Learning outcomes: Empathic qualities in complex design processes

The identified cognitive qualities of empathy relevant for the design process were multi-functionality, symbolism and brand recognition. The emotional qualities of empathy that were identified were corporate values that might contribute to corporate social responsibility, as well as, social interaction and colour associations. The compassionate qualities of empathy in this study were mutual benefit, positive consequences in society and faith in the individual's devotion and dedication. The approach thus contributed to a complexity that stimulated flow and creativity.

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# TEACHING ETHICS IN ENGINEERING AND DESIGN, THE NECESSITY OF CONCURRENT ENGINEERING

**Carlos Alberto GONZÁLEZ-ALMAGUER[1], Fernando ARRIAGA[1], Jose MANRIQUEZ[1], Alejandro ACUÑA[1], Grecia GONZALEZ[1], Ricardo HUERTA[1] and Joaquim LLOVERAS[2]**
[1]Monterrey Institute of Technology and Higher Education (ITESM)
[2]Technical University of Catalonia (UPC)

**ABSTRACT**
Mechatronics engineering is a discipline, which links together three different areas: mechanics, electronics and digital systems. This major, has proven its use in industry, it allows them to have professionals with integral knowledge and an overall notion of the developments of most machines that are working in the industry. Currently any process in a factory or business strives to become automatised and as such, this tendency has come to be widely regarded as the aim of any developing industry today.
Simultaneously, automation could come to be a problem when the engineer masterminding the operation of creating a new system does not have an integral formation with ethics at its core. Raw knowledge and the union of different theories and ideas will not guarantee an efficient and reliable new system for every stakeholder. For this reason it is relevant to create and teach a procedure to design a new methodology constructed on ethics, in order to design products and processes with a social and sustainable vision and, of course, high revenues.
The main goal of pretty much any major is to provide society with the means and tools to improve, to fix and to create. In particular to design from ethics is to incorporate an innovate engineering approach, the designers will realize that as members of a society there is responsibility and thus, they must be instructed and their endeavours must contain a strong set of principles, rights and values that can be support all that implies a society, always considering the actual and future generations, as well as the ecosystem they live in.

*Keywords: Design, ethics, eco-design, sustainable*

## 1 INTRODUCTION
The actual world is fully globalised and mostly inhabited by a society which makes profit maximization a priority. According to Goldratt, the goal of any business is to earn an income not only today but to also secure it for the future. The effort and sometimes obsession to boost profits has turned in one of the most significant causes of the recent and very often cases where, due to design flaws, either premeditated or unintentional accidents have damaged end-users and produced large economic losses. This means that economic, political and commercial interests are arguably directly responsible for the release of flawed products.
There are some cases around the world where large car companies have caused fatal injuries, as well as economic losses to the companies themselves, for example when they are forced to do a complete recall of their vehicles to fix the flaws. To name a few of them, Toyota, General Motors and Ford have been involved in this kind of situation [1,2,3]. One of the most dramatic cases, because the flaw happened while being broadcasted in worldwide television, occurred when Space Shuttle Challenger broke apart during operation. The project was launched in spite of the flaw being reported by engineers to program managers at NASA [4]. However, for the program managers it was politically important to continue the space shuttle lift off. The project was a massive failure because of administrative negligence and lack of ethics.
Elsewhere, another example happened in Mexico City when metro line 12 was built. In this case, politicians and contractors put their own interests before the safety of the people. Fortunately, there were no accidents, but additional funding was required to fix faulty railroads and station platforms [5].

Finally, one of the most known and outrageous cases of bad engineering design and manipulation of information was the Ford Pinto case, in which it was evaluated if it was cheaper to pay claims for caused deaths than to change the entire design [6].

The Design and Ethics teachers in Monterrey Institute of Technology and Higher Education, feeling a sense of responsibility towards their students, have taught methodologies to innovate products with higher functionality and lower cost, but they are trained to do so from the point of view of ethics, sustainable development and social development impact. This paper is born from the concern of students of Mechatronics Design course, from August to December 2013, who within their competence for sustainable development adapted agricultural machinery to operate using renewable energy. The optimization of the equipment involved high productivity and quality. These innovations were implemented in the greenhouse of an orphanage, so they could generate their own food at the lowest cost.

Teachers in collaboration with students have developed a simple methodology. It is based on an institutional ethics program, sustainable and social development practiced in the University, and of course in methods designed for the academic classes. The methodology generates the interface between the institutional programs and academic design programs which are used to teach to college students.

## 2 ETHICS IN MONTERREY INSTITUTE OF TECHNOLOGY AND HIGHER EDUCATION

ITESM has taken actions to the ethics education of their students [7]. The Mission of the Institute is to prepare upstanding, ethical individuals with a humanistic profile, who are internationally competitive in their professional fields, and where a humanistic profile is understood as having respect for the dignity and solidarity of the other people. In curricular approaches, especially in the field of engineering practices, incorporating ethics and forcing civic reflection is essential at the dawn of this century to institute a humanistic vision.

The *Quality Enhancement Plan* (QEP) of ITESM [8] aims to improve processes of teaching and learning in the area of ethics and citizenship, everything done in a structured and long-term growth (2008, p.10). The goal of this program is to strengthen students in their ethical and citizenship competencies that can be an asset in their academic and professional lives (2008, p.11). There are four competencies to be developed:

First competency

Reflect, analyze and evaluate ethical dilemmas related to oneself, their practice and their environment. In particular, the pursued objective is that graduates take their personal and professional decisions based on ethical criteria. This will involve three steps: First of all, acknowledgement of the need for ethics for their personal and social development; second, the development of the capacity for rational application of the identification and resolution of ethical dilemmas processes; finally, the development of the capacity for understanding and furthermore analyzing the fundamentals so they can build their own answers to ethical questions and objectively criticize the answers that other people have.

Second competency

Respecting people and their environment. The idea is that graduates consider how their professional, personal and social performance affects other people and their everyday environment. Specifically, the student is supported by a solid foundation of the principles that support human dignity to solve ethical problems. Also they are able to recognize that respect and tolerance are fundamental to social life principles.

Third competency

To understand and be sensitive to the social, economic and political reality. The goal for graduates is to be updated on the social, economic and political events, so they will be able to judge with an educated criterion. At this point, it should be highlighted that it is intended that students show willingness to engage in solving the problems of the community, especially when it comes to marginalized communities.

Fourth competency

Act with solidarity and civic responsibility to improve the quality of life of its community and especially of marginalized communities. Graduates are encouraged to participate in organizations or activities that contribute to the improvement of their community. The aim is that students are able to plan, implement, evaluate and engage in coordinate solidarity actions to solve problems in which to

apply their knowledge, including their career, and enrich their learning when reflecting about the experience.
This training encourages the development of individual autonomy, participation as a citizen in the community and an awareness of being part of humanity, which of course brings us to the most expensive of Kant convictions: autonomy, dignity and humanity applied to oneself and to the others. So, how to create this consciousness to students? What pedagogy and didactics are used for this extraordinary project? The answer includes a primary knowledge base which starts what might be called <<the humanistic view of the learner>> and on which it could be build objective and well-supported ethics and citizenship. This view is known as the fundamental foundation of <<humanistic profile>> which fits under the ITESM graduate profile. This vision is understood as the recognition of the legacies that humanity has given, as well as awareness of the situation. It is always open to human creativity through imagination and its implementation, creating new realities founded in an ethics and citizenship according to which requires time. This is engineering with a humanistic view.

## 3 DEVELOPMENT AND PROCEDURE

The Mechatronics Design course is one of the latest courses in the study plan of Mechatronics Engineering, by the time students take this course they have completed about 90% of all subjects, including three courses about ethics.
The first step of the methodology is to apply an audit of values and ethics in engineering on the first day of the course. The audit is designed by Professor Fernando Arriaga who teaches ethics at the college. Through solving scenarios and questionnaires in which students face ethical dilemmas, their commitment to sustainable and social development can be measured.
The result of the audit would allow teachers to select a specific case for each student from a database of cases in ethical engineering. In this way, it would be possible to sensitize them to all the professional competences. Reading cases and the consecutive discussion of the solutions are made concurrently with the reaffirmation of ethical skills, sustainable development and social development as well as product design techniques.
During the last months, the developers would be analyzing worldwide cases about flawed design, situations where the production process has contaminated the environment or damage to human and successful social development projects using engineering design. The actual database consists of 200 cases continuously increasing every semester.
The next phase is an open discussion between teachers and students in which they determine the ethical implications. The students are asked to research in real time the root cause of the problem, the proposed solutions and the economic analysis of saving a well-designed product versus a poor one.
Regarding a sustainable development approach [9], the project is intended to create awareness in the students about the impact our projects have in the planet, caused by current products and manufacturing processes. The forward-looking solutions cannot solve the problem only for the present, the students do discuss the impact of the solution when the product is in the horizon time of their life cycle. During these readings, students are taught to measure the carbon footprint and ecological footprint.
The carbon footprint measures the amount of greenhouse gases that are emitted as a result either directly or indirectly from the creation of a product, so for any product that students design the gases emitted are measured in two ways: from each raw material and from the finished product. Additionally, the gases emitted by the transportation of the products and of the final destination of the product (with consumer) are considered.
The ecological footprint is an environmental indicator of how a human community has affected its environment, considering both the resources and the waste generated to preserve the pattern of production and consumption of the community. It is defined as the area required to produce the resources consumed by an average citizen of a particular human community, as well as what is needed to absorb the waste it generates, regardless of the location of these areas. Broadly speaking, the methodology for calculating the ecological footprint is based on estimating the necessary area, which is selected in hectares to know the consumption associated with food, forest products, energy expenditure and the direct occupation of the land.
The ecological footprint quantifies objectively the environmental impact and may be benchmark in environmental objectives that are proposed by organizations. Its main objective is to evaluate the

impact on the planet in a certain way of life style and, it is compared to the planet's biocapacity. Consequently, it is a key indicator of sustainability.

Finally, the life cycle analysis is a process to assess the environmental burdens associated with a product, process or activity as objectively as possible. It is done identifying and quantifying the matter and energy usage and wastes produced in the environment; in order to determine the impact that the use of such resources have, so it will be simpler to evaluate and implement environmental improvement strategies. The Life Cycle Analysis (LCA) includes the complete cycle of the product, process or activity, taking into account the steps of extraction and processing of raw materials; production, transport and distribution; use, reuse and maintenance; and recycling and disposal of waste.

The third element of ethical engineering design is social development [10]. As one of the Latin American countries with serious social underdevelopment, Mexico is inhabited by communities in extreme poverty. Additionally, the proximity of the border with the United States for decades have undergone a process of migration from rural areas to both cities and abroad, which has exacerbated the phenomenon of extreme poverty for 70 years, when ITESM was founded. Graduates should have a humanistic vision to become agents of change in their own community. If the University community design products and their manufacturing processes considering ethics and a social approach, and all of them are sustainable, the result will be helping to create small business in these marginalized areas that will help to reverse poverty.

The students work concurrently in the awareness through reading cases; the concurrent work is based on the Mechatronic design model proposed by Manriquez, Gonzalez, Riojas and Lloveras [11] in which teachers make an emphasis on eco-design and normativity according to national and international security standards. Figure 1

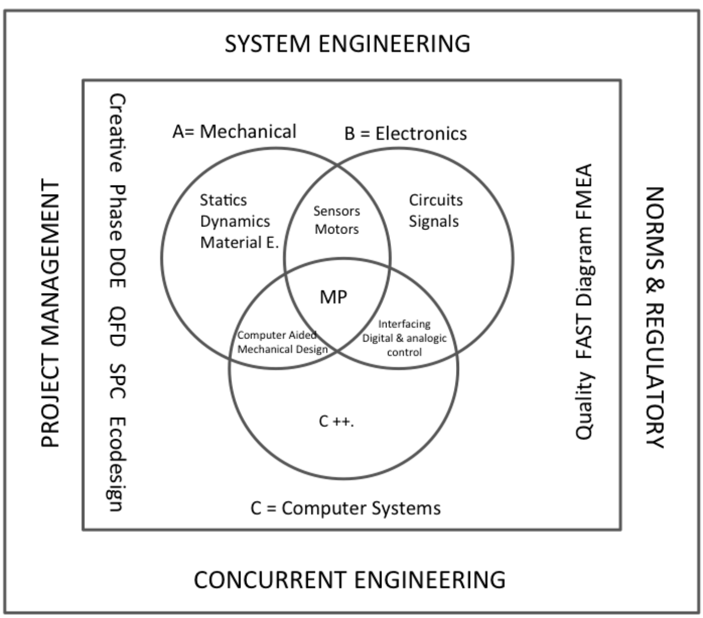


*Figure 1. Mechatronic design model*

At this stage, it is introduced the analysis and design of experiments for economy engineering, so it is possible to determine whether the design of the raw material and the final product is ideal with an acceptable cost. The first option in engineering design is to make products at the lowest cost to have the most profits. Introducing the design ethics within the framework, it allows students to evaluate the impact of the first option and its possible cost. The procedure constantly iterates until the combination of components and processes that results in the best product is found. The result includes a manufacturing process friendly to the environment and the community and it implies the best revenues.

After applying design methodologies and making its economic assessment, the final step is proceed to do a new audit with the students to determine the degree of sensitization to ethical design. The last evaluation consists in a final project, the second component is a survey specifically designed to measure learning and the solution of a case where the student will share its knowledge and awareness by giving the best solution.

### 3.1 Success cases

During the semester August – December 2013 in the Mechatronics Design assignment there were activities with the finality to improve the technical knowledge as well as the awareness of sustainability and community service. Students were to select a civil organization (OSC for Spanish acronym) to support by executing a project designed by themselves. The organization in question was located in a marginal and poor area in the state of Guanajuato, Mexico. The project consisted in the reconversion of agricultural machinery to be sustainable and to work with renewable energies for the production of dehydrated tomatoes cultivated in a greenhouse obtained by donation.

Regarding the project requirements, the technical solution that the students had to propose was to make a redesign of the machinery, and make it functional to the needs and possibilities of the OSC, they have to consider the electrical consumption, as well as to try and reduce the maintenance and operation costs. Additionally, the operation and maintenance of the machinery should be very simple, and intuitive to be carried out by any unskilled worker. The main objective of these requirements is to increase the profitability of the greenhouse and thus, the OSC benefiting from such situation.

All these requirements make the project something different from what any student has done before. Most of the team´s integrates were senior students of their majors, but in projects developed in previous semesters, they didn't have to worry about electrical consumption, material resistance, maintenance cost, or the easiness and practicality of the actual operation. The project and said requirements also contrasts with projects in the city in a stable company with highly qualified people and a steady income, where these previous considerations (maintenance costs, easiness of the operation, etc.) held no priority whatsoever in the design process [9].

The concurrent focus was an example of the application of the methodology. It was useful to identify the relationship between; firstly, the design, next, the sustainability of the project focused in the uses of alternative energies by using organic waste to produce biogas and finally, the ethical issues. All these requirements were used together, since the creative phase, the brainstorm phase, and the mental maps that were conducing to the best solution.

In the bio design assignment, for the industrial design major, an activity was designed where the objective was the attainment of the required competences for sustainable development. The objective was made possible by linking the disciplines of bio mimics, biomimetic, bionics, and design, and more importantly the application of all these disciplines, along with assuming the moral and ethical responsibility in the design of sustainable products.

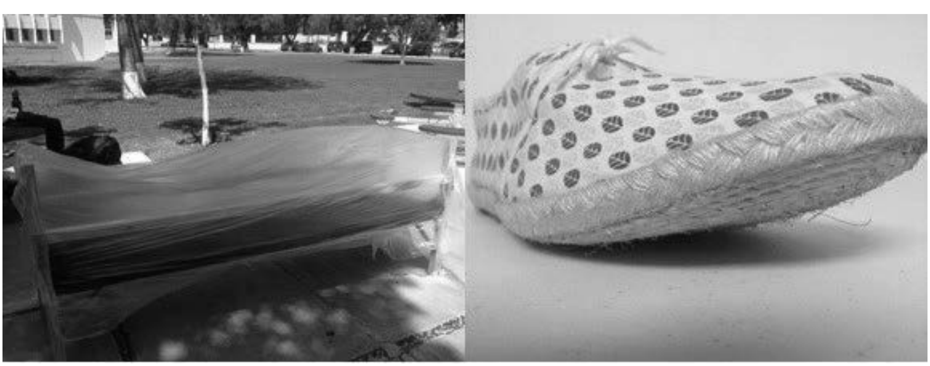

*Figure 1. Products designed with ethics design focus*

The results the project yielded were the design and fabrication of a low cost slipper using recycled materials (see figure 2 on the right), and a paper dish made with biodegradable material (see figure 2 on the left).
The project includes the creation of a social company to produce both products, without forgetting the social, economic and sustainable aspects, in marginal points of Querétaro city.

## 4 CONCLUSIONS

After the projects the students could witness firsthand the radical importance of the application of engineering with human sense, especially in developing economies such as Mexico. Only through methodologies such as the one presented in this project, notably teaching students how to solve real world problems helping their communities, is the way they can change and reduce the educational, economical, and social gap so remarkable between developing and developed countries. Revenues and engineering with human sense are compatible; the key is a strong emphasis in design solutions from a concurrent vision maximizing the relevance of ethics, as well sustainable and social aspects.
The result of the experiences designed created a methodology that involved different areas. It was dealt not only with academic and professional businesses but also with moral and ethical issues. The methodology guarantees a process that teaches the student all the perspectives of how to solve a problem and the techniques to contemplate all the needs and possible solution even when the problem involves different areas of study and thus, justifies a new focus for the development and growth of professionals. It was observed that the students do not always contemplate the different stakeholders in the project but that the methodology is another step towards such issue and their integral formation. The implementation of ethics in engineering is another step towards making possible a more equitable distribution of opportunities, raising the awareness in the professional to help those in need and, creating or innovating new products or processes hand in hand with high profits and revenues to industry all from the avail that gives ethics and a vision of a sustainable world.

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# AESTHETICS VERSUS USABILITY: WHAT DRIVES OUR PRODUCT CHOICES?

**Stephen TRATHEN**[1]
University of Canberra, Australia

**ABSTRACT**
This research examined the influence of usability and aesthetic/emotive characteristics on prospective buyers' preferences in pre-purchase product selection. Results indicate that while both characteristics are important, aesthetic/emotive factors are dominant and can counteract negative perceptions of usability-at least in regard to the products studied. This research contributes to our understanding of the relationship between a product's usability and aesthetic factors, and how these are perceived by users at different stages of product selection. Both product design and design education could be improved through a better understanding of users' interactions with products. How users perceive and respond to products, how their responses change over time and with varying levels of contact with the product, and ultimately how user satisfaction emerges from these processes is integral to such improvements.

*Keywords: User behaviour, product design*

## 1 INTRODUCTION

What happens when a customer is in the market for a particular product, and is confronted with multiple models, all basically doing the same thing? What makes them choose to buy one version rather than another? Researchers, designers, ergonomists and marketers are all interested in that decision-making process and how to influence it. They all aspire to a common goal: to produce items that lead to overall consumer satisfaction with the product [1], [2], [3], [4].

Researchers from various backgrounds within this multidisciplinary field are contributing converging ideas and sharing knowledge on how best to provide optimum levels of overall product satisfaction. It will be important to maintain the present interest in this field, to ensure that the processes used to develop new products take account of the need for participant feedback on a wide range of issues at several stages during the design process. Only in this way can products be developed which will provide multi-dimensional satisfaction to users, combining good usability with the capacity to evoke aesthetic and emotional pleasure.

As a contribution towards answering these questions, this research examined the influence of a range of perceived product attributes during pre-purchase decision-making. Drawing upon a previously developed conceptual framework for product evaluation, two empirical studies were conducted with a total of 86 participants to gauge perceptions of products' 'usability' and 'aesthetic/emotive' characteristics. Clock radios and cordless kettles were used as examples of domestic electrical appliances with differing levels of user-interface complexity.

## 2 THEORETICAL FRAMEWORK

### 2.1 Hypotheses

Three hypotheses were developed to guide this research (see summary Box 1). The first two relate to the initial stage of potential buyers' consideration, when product images are viewed in a catalogue or online (Stage 1). The third relates to the later stage of consideration, when potential buyers can handle, but not use, products in-store (Stage 2).

*Stage 1 hypothesis:*

1a) aesthetic/emotive influences would be stronger than usability influences when potential buyers express a preference between different models of a simple product on the basis of viewing images (and that this would be less evident when choosing between models of a more complex product).

1b) when these potential buyers are asked to differentiate between how much they like versus how likely they would be to actually buy a product, the influence of usability factors would become stronger than aesthetic/emotive factors, and this would apply to both simple and complex products. This was suggested to test the idea that actually purchasing a product would be more influenced by practical considerations than by reactions to its appeal. For example, some might *like* a blue kettle because of the unusual colour, but prefer to *buy* a white one in order to tone with an existing kitchen colour scheme.

*Stage 2 hypotheses:*

2) usability influences will remain stronger than aesthetic/emotive influences in product preferences, and that this would apply to both simple and more complex products.

**Box 1: Hypotheses summary**

**Hypothesis 1**:

*The influence of a model's aesthetic/emotive characteristics relative to its perceived usability characteristics will be:*

*(Part A) greater for different models of cordless kettle (a 'simple' product) than for different models of clock radio (a more complex product)*

*(Part B) greater when influence is measured in terms of the strength of association between ratings of product characteristics and ratings of how much people* ***like*** *each model, rather than for ratings of how likely they would be to* ***buy*** *each model.*

**Hypothesis 2**:

*The influence of usability characteristics relative to aesthetic/emotive characteristics will be greater for both products in stage 2 (handling products) than in stage 1 (viewing photos).*

## 2.2 Conceptual model and attributes

The research drew upon two elements of previous work.

The first element of earlier work was a conceptual model for product evaluation developed to explain the genesis of overall product satisfaction [5]. The model highlights interactions between perceived *product characteristics* (such as functionality, usability and aesthetic/emotive characteristics) and *user characteristics* (such as needs, skills and personality) (see Figure 1). These interactions lead to *evaluative responses* which together determine overall product satisfaction: that is, the extent to which a user will like the item, wish to buy it, and continue to use and value it after purchase.

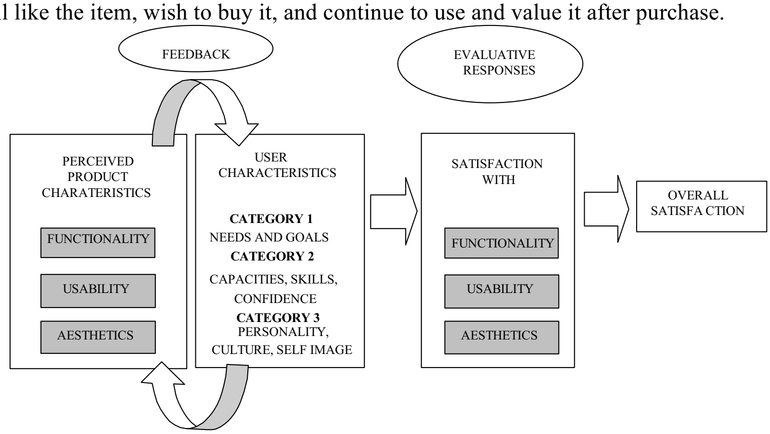


*Figure 1. Product evaluation model*

Applying the model means that product evaluation criteria should include:

- effectiveness in meeting users' needs and goals;
- efficiency in users' performance (e.g. ease of use, errors and safety)

- impact on users' feelings regarding aesthetic/emotive product factors; and
- overall satisfaction, a combination of the relative importance of the factors above.

The second element was a range of characteristics generated through the use of focus groups relevant to each identified category of product characteristics: functionality, usability and aesthetic/emotive [6].

## 3 METHOD

For the purposes of this study characteristics generated in the categories of usability and aesthetic/emotive were refined to a matrix of 20 attributes and these were used to design a participant questionnaire. Participants completed the questionnaire to rate products against these 20 attributes and also gave an overall rating against a further two questions: how much they liked, and how likely they would be to buy the product. The research was undertaken in two stages:

- Stage 1 (n=49: 36.7% (18) male and 63.3% (31) female) where participants were able to view images of the products. This stage replicated product assessment where potential buyers view images in a catalogue or online.
- Stage 2 (n- 37: 43.2% (16) male 56.8% (21) female) where participants were able to handle – but not use - actual products. This stage replicated product assessment where potential buyers examine the product in-store.

The products chosen were cordless kettles (typifying a simple appliance with functionality limited to filling, turning on/off and pouring, Figure 2) and clock radios (typifying a more complex appliance with a range of functionalities including setting an alarm, changing radio stations and adjusting the time, Figure 3). Product selection criteria also included: a sufficient range of usability and aesthetic/emotive attributes, an adequate range of models from different manufactures, likelihood of participant familiarity; and cost and portability. Six models of each appliance were studied.

*Figure 2. Selected cordless kettles*

*Figure 3. Selected clock radios*

Participants were asked to rate each of the six models of the two product types against the 42 questions, resulting in 504 (42 x 12) questions per participant. Order of product type (kettle, radio) and orders of models within each product were balanced over participants, as were orders of the individual items within each questionnaire.

## 4 DATA ANALYSIS

Participant ratings were subjected to principal components analysis and scores on each factor were used in linear regression analyses for each model and a linear mixed model analyses to determine the extent to which they had a statistically significant influence on overall 'like' and 'buy' ratings. These methods were used to produce two measures of the influence of usability and aesthetic/emotive factors on the overall ratings: mean effect size and mean correlation coefficients. Differences between the two measures were also compared.

## 5 RESULTS

### 5.1 Stage 1

As shown in Table 1, the effect of aesthetic/emotive factors was larger than that of usability factors on the overall rankings for both products, whether measured by mean effect size or mean correlation coefficients. For clock radios, usability had a relatively greater influence on both like and buy ratings than it had for kettles. This can be seen by comparing clock radios and kettles in terms of the differences between effect sizes of these two factors. For example, the difference between 0.193 and 0.771 (kettles - like) is greater than that between 0.518 and 0.853 (clock radios - like). Similarly, correlations with ‘like’ and ‘buy’ are higher for the aesthetic/emotive than the usability factor, but the difference is less for clock radios (38% and 28% for ‘like’ and ‘buy’ respectively), compared with kettles (61% and 55% for ‘like’ and ‘buy’ respectively).

*Table 1. Relative effects of product attribute factors Stage 1*

| | **Kettles** | | | | **Clock radios** | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean effect size | | Mean correlation coefficients | | Mean effect size | | Mean correlation coefficients | |
| | Like | Buy | Like | Buy | Like | Buy | Like | Buy |
| Usability factors | 0.193 | 0.218 | 0.406 | 0.387 | 0.518 | 0.584 | 0.511 | 0.551 |
| Aesthetic/emotive factors | 0.772 | 0.800 | 0.652 | 0.600 | 0.853 | 0.874 | 0.706 | 0.705 |
| % difference between factors | 300% | 267% | 61% | 55% | 65% | 50% | 38% | 28% |

Results show the percentage difference between usability and aesthetic/emotive effects is greater – indicating a greater influence of aesthetic/emotive factors relative to usability – for ‘like’ ratings than for ‘buy’.

### 5.2 Stage 2

As shown in Table 2, results from Stage 2 were similar to Stage 1 in that the effect of aesthetic/emotive factors was larger than that of usability factors on the overall rankings for both products, whether measured by mean effect size or mean correlation coefficients. This effect was greater for aesthetic/emotive factors, as can be seen in the difference in mean ‘effect size’ between factors for both ‘like’ and ‘buy’ ratings. The greater effect of aesthetic/emotive factors on overall product ratings is also evident in the greater magnitude of mean correlations between this factor and both ‘like’ and ‘buy’ ratings, compared with the size of correlations for the other two factors.

*Table 2. Relative effects of product attribute factors Stage 2*

| **Factors** | **Kettles** | | | | **Clock radios** | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean effect size | | Mean correlation coefficients | | Mean effect size | | Mean correlation coefficients | |
| | Like | Buy | Like | Buy | Like | Buy | Like | Buy |
| Usability | 0.433 | 0.266 | 0.519 | 0.430 | 0.235 | 0.316 | 0.459 | 0.490 |
| Aesthetic/emotive | 0.644 | 0.793 | 0.643 | 0.626 | 0.689 | 0.852 | 0.670 | 0.709 |
| % difference between factors | 49% | 198% | 24% | 46% | 193% | 44% | 46% | 45% |

### 5.3 Comparison of Stage 1 and Stage 2 vis a vis hypotheses

Data from both stages are compared in Table 3. In absolute terms, the influence on ‘like’ and ‘buy’ ratings of usability was almost always less than that of the aesthetic/emotive factor. Therefore, to investigate hypothesis 2, the relative effect of usability is shown in terms of *how much* greater (in percentage) the aesthetic/emotive influence is, relative to the usability influence. According to hypothesis 2, percentages will decrease for both kettles and clock radios in Stage 2, relative to Stage 1. The second hypothesis, that for both simple and more complex products the influence of usability characteristics would be stronger than aesthetic/emotive characteristics when users were able to handle products (rather than just viewing images), was not supported by the results. Stage 1 results showed usability had a relatively greater influence on both like and buy ratings for clock radios than it had for kettles, but these were not replicated in Stage 2. For example, the differences are 49%, 198%, 193%

and 44%, for kettle like and buy, and clock radios like and buy, respectively (see Table 3). Similarly, correlations with 'like' and 'buy' are higher for aesthetic/emotive than usability factors, and differences are 24%, 46%, 46% and 45% for kettle like and buy, and clock radios 'like' and 'buy' respectively.

*Table 3. Comparison of influence of usability and aesthetic/emotive factors Stages 1 and 2*

| | | % difference between factors in effect sizes | % difference between factors in correlation coefficients |
|---|---|---|---|
| | | **Stage 1** | |
| KETTLES | 'like' | 300 | 61 |
| | 'buy' | 267 | 55 |
| CLOCK RADIOS | 'like' | 65 | 38 |
| | 'buy' | 50 | 28 |
| | | **Stage 2** | |
| KETTLES | 'like' | 49 - less | 24 - less |
| | 'buy' | 198 - less | 46 - less |
| CLOCK RADIOS | 'like' | 193 - more | 46 - more |
| | 'buy' | 44 - less | 45 - more |

For kettles, there was some support for the hypothesis that usability would be more influential than aesthetic/emotive characteristics as more interaction with the product was allowed: in all four cases the percentage difference between usability and aesthetic/emotive influence was greater in Stage 2 than in Stage 1. That is usability tended to have relatively more influence on people's evaluation of kettles when they handled the actual products (Stage 2) than when they only saw photographs of them (Stage 1). For clock radios however the hypothesis was unsupported. In three of the four cases the percentage difference between usability and aesthetic/emotive influence was *greater* in Stage 2 than in Stage 1. That is usability tended to have relatively *less* influence on people's evaluation of clock radios when they handled the actual products.

### 5.4 Caveats

In any study using lengthy questionnaires, motivation levels may vary over the course of questions, with participants possibly skimming some in an attempt to finish earlier. This potential issue was addressed by advising participants of the time commitment in advance, ensuring sufficient time was allowed and creating a relaxed environment in which to respond to the questionnaire. Another potential limitation regarding participant characteristics is the possibility of varying levels of experience with the product types. This risk was reduced by selecting commonly used appliances designed for use by a broad range of users. However if studying more complex products, a specific question regarding participants' levels of experience and knowledge of the product may be useful.

## 6 DISCUSSION

In both stages, the influence of the aesthetic/emotive characteristics was greater than the influence of usability-related characteristics for both kettles and clock radios. Hypothesis (1a) - that such a difference in influence would be greater for kettles, being a simpler product, than for clock radios, representing a product with a more complex user interface - was supported in Stage 1 but not in Stage 2. Neither stage provided evidence to support hypothesis (1b). That is, aesthetic/emotive influences were stronger than usability influences, even when potential buyers differentiated between how much they liked, versus how likely they would be to actually buy, the product.

Evidence was mixed in relation to hypothesis 2, that is, that usability characteristics would be more influential than aesthetic/emotive characteristics when users are able to handle products than when only able to view images of products, and this would apply to both simple and more complex products. For kettles, there was some support for this hypothesis: that is, usability tended to have relatively more influence on people's evaluation of kettles when they handled the actual products (Stage 2) than when only viewing images (Stage 1). For clock radios, however, the hypothesis was unsupported. The reasons for this are not readily apparent. It had been expected that the greater complexity of the clock radio user interface would have been more evident to Stage 2 participants, who could handle and inspect the actual products, and that this would have increased the salience of usability-related issues. It was also expected that the comparatively simple cordless kettles might be perceived as being relatively equal in their usability, reducing the influence of this factor for them. One possible explanation for the relatively low influence of usability under the product-user interaction conditions of this study is that participants might have used a more holistic or global approach to form an overall impression of the product, rather than examining and evaluating individual attributes. Such an approach might in fact be encouraged by the perception that a product is relatively complex, to the extent that some may see specific evaluation of its usability as too difficult. It was also expected that usability would be relatively more influential for products with more complex user interface designs, such as clock radios. In such cases, variation in the usability of the interface seems more likely to affect people's capacity to use the product successfully. However, it may be that such effects only become evident after purchase, when people actually (attempt to) use products for their intended purposes.

## 7 CONCLUSION

This study contributes to our understanding of the influence of aesthetic and usability factors on product selection by quantifying the relative strengths of these associations at different points of pre-purchase production interaction. The fact that some 'common sense' hypotheses were not supported by the evidence highlights the importance of such experimental studies. Future investigation in this area could build upon this work by examining similar product interactions in the post-purchase phase, when the product is actually being used in the real world.

A better understanding of usability and aesthetic factors as key drivers of the user-product interface is of critical importance to the fields of marketing, ergonomics and product design. If these professions had a better understanding of the product evaluation process and how user satisfaction stems from perceptions of product characteristics, products could be better designed and marketed with the user in mind.

Achieving this outcome will require changes to undergraduate and postgraduate education for these professions, based on the identification of areas of potentially shared knowledge. For example, the fields of psychology and behavioural sciences, which underlie so much of the user-product interaction, have in the past largely been inaccessible to most design undergraduates. New platforms for sharing knowledge across such traditional disciplinary silos are now emerging. For example, recent works developing a shared vocabulary to enable cross-discipline communication and articulating the application of behavioural sciences to design [7], [8] are successfully being used in the author's undergraduate design courses. Future developments should build on this base through inter-disciplinary teaching, plain language texts and cross-discipline team projects.

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## Chapter 17

# TEACHING DESIGN TECHNOLOGY

# ACCOMMODATING DIFFERENT LEARNING STYLES: BRIDGING MATH AND FORM

**Nis OVESEN**
Aalborg University, Denmark

**ABSTRACT**
Design engineering educations often struggle to accommodate a highly diverse group of students as it combines an equally diverse range of topics in one education. This paper investigates how a specific course, *Mathematics and Form*, integrates two distinct areas into one course with the aim of facilitating learning across this diverse group of students. The paper is based on a survey with 99 former participants of the course as respondents. The results of the survey imply that certain types of students benefit from the combination of mathematical theory and practical exercises related to basic shapes and form, whereas other types of students do not. The results thereby underpin that learning is typically based on individual preferences and that cross-disciplinary educational programmes have to accommodate this.

*Keywords: Design education, mathematics, form, Grasshopper 3D, learning*

## 1 INTRODUCTION

Higher educations within the field of industrial design engineering often experience a dilemma when developing curriculums that need to accommodate two distinct archetypes of students: the mathematically oriented and engineering-focused students on the one hand, and the design-focused and aesthetically oriented students on the other. In the Industrial Design engineering curriculum at Aalborg University several courses are developed to bridge the relatively wide span of heavily engineering related content with traditional design methods, tools and aesthetics. However, the large diversity in students makes it difficult to plan and conduct teaching activities and facilitate learning spaces that are ideal for all types of students at once.

At the second semester of the bachelor education a mathematics course is held with a focus on introducing the students to fundamental mathematical concepts, methods and tools in order to enable them to carry out calculations with vectors, matrices and various algorithms. This course is thereby laying the ground that later engineering related courses build on. However, students have earlier criticised the course for being too disconnected from the education's focus on design and architecture. For the last couple of years, the course programme has therefore been slightly changed with the underlying purpose of *also* establishing a foundation for seeing and understanding form as representations of mathematical expressions and algorithms. Thereby hopefully preparing the students for more skilled and knowledgeable use of 2D and 3D modelling software in a design-related context.

A series of workshops were introduced as part of the course and acted as an introduction to generative modelling of digital form with the use of a plugin called *Grasshopper* [1] for the 3D modelling suite *Rhino*. Grasshopper is a graphical algorithm editor that with only little or no skill in programming and scripting allows users to generate shapes and form from mathematical expressions. As an output of the course, the students developed a series of mathematically defined shapes and thereby established the valuable connection between mathematics and form through own experiments and applied theory.

Among other related areas, previous research efforts have been looking into some of the implications of digital versus tactile learning [2] and how to break down barriers between virtual and physical models [3]. It has also earlier been investigated whether or not 3D graphics is beneficial when learning advanced mathematics [4]. However, research on learning about form through mathematics seems to be lacking. This research paper aims at this gap and is driven by the following question: *Does the combination of learning mathematics and "algorithmic form generation and visualisation" improve the design students' understanding of form?* The paper provides an in-depth description of the

motivation and rationale behind the course and an evaluation of the experience and learning output of the students.
The rest of the paper is composed as follows: In the following section 2, the structure, aims, and content of the course is presented as well as some of the work made by the students. Section 3 presents the research setup and the applied research method. The results of the research effort is shown in the fourth section, and finally is section 5 concluding the paper with a discussion on the use and impact of using algorithmic form generation in bridging the gap between math and form.

## 2 COURSE STRUCTURE, AIMS, AND CONTENT

A mathematics course has always been part of the second semester at the architecture & design engineering educations, but a recent curriculum revision has slightly broadened the scope of the course to also include aspects related to digital form. The course were retitled *Mathematics and Form*, and the aim and of the course were rewritten: "*Students should obtain insights in fundamental mathematical concepts, methods, and algorithms that are necessary for efficient use of digital tools for 2D- and 3D modelling in a design related context.*" The new learning goals of the course further explicated the strong relation between math and digital modelling.
The full course programme contained 15 lectures and 7 workshops. Three of the lectures and five of the workshops were directly related to generating and analysing form with the Grasshopper plugin, whereas the rest of the lectures and workshops were about basic linear algebra and vector functions for describing curves. Figure 1 below illustrates the structural layout of the course.

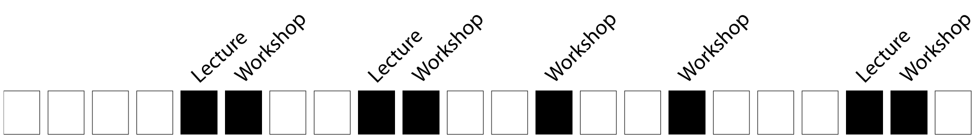


*Figure 1. The layout of the course with black markings indicating activities related to form generation with Rhino and Grasshopper*

### 2.1 Exercises with generating form

During the course, students worked with exercises that illustrated the mathematical concepts through visual representations with Grasshopper. Two exercises are exemplified in Figure 2 below.

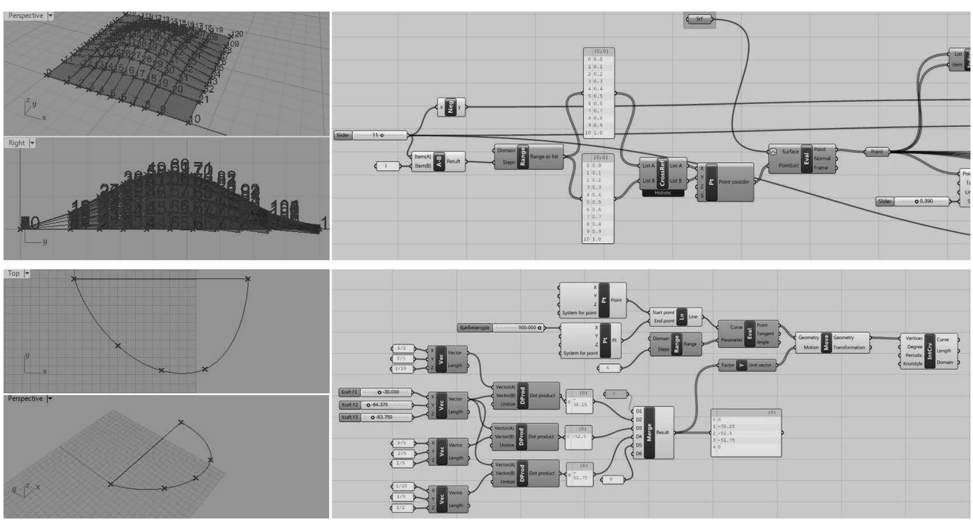

*Figure 2. Exercises from two of the workshops in the course programme. To the left are visual representations generated in the 3D modelling software Rhino from the graphical algorithm editor in Grasshopper shown to the right*

The basic forms and shapes were generated from the scripts made in the graphical algorithm editor during five workshops with supervision. The cumulative work made by the students during the workshops was used as the basis for an individual, oral examination in the whole course programme. The students were able to solve the assignments in the workshops without any prior skills in programming. As it is exemplified in Figure 3 below, a script is built up by dragging various tools or functions to the grasshopper canvas and adding inputs to each of them in order to produce the wanted output.

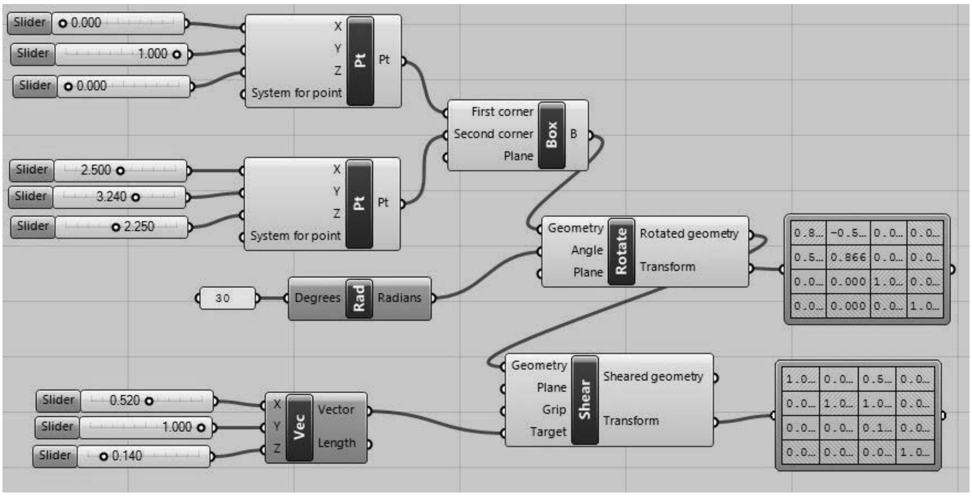


*Figure 3. Various tools and functions are dragged to the grasshopper canvas. Input/output-flow goes from left to right, and finally creates the wanted shapes through various tools for drawing geometry*

## 3 RESEARCH METHOD

A part of the motivation for this research project has been a recent curriculum revision and the idea for the study has sprung from this. It has been carried out primarily as a survey-based study [5] with earlier participants of the mathematics and form course as respondents, supplemented with an interview with the coordinator and primary lecturer of the of the course programme. The students on the 2nd semester bachelor in participated in the course over a period of three months in the spring 2013, and the survey was carried out during the following winter. In the survey, the students were presented to a total of 10 questions. Of these, the first three questions focused on the students' relation to the education and participation in the course. The next six questions concerned the students' experiences and learning related to the combination of math and exercises on form generation. The last question sought to uncover how the students would define their favoured ways of thinking; primarily mathematically oriented and engineering-focused or primarily design-focused and aesthetically oriented. A total of 175 students participated in the course programme and 99 of these completed the online questionnaire for this study.

As mentioned, the survey was supplemented with an interview with the course coordinator and primary lecturer in order to get a more qualitative view on the students' learning output. This was carried out as a semi-structured interview [6] as a written correspondence.

The further work with the survey data has been carried out manually through a process of looking for significant deviations or interesting results from graphical representations of the data sets.

## 4 RESULTS OF THE INVESTIGATION

In this section, some of the results of the survey will be presented and crossed in order to illustrate the most significant results.

The first year of the bachelor programme is a common education for all students at Architecture & Design. After this year, students choose either an Arch/Urb programme or an industrial design programme. This survey is focused on a 2nd semester course and therefore includes students from both programmes. The distribution is shown in Figure 4 below. Approximately two thirds of the students typically choose to study on the arch/urb programme after the first year, and the respondents in this survey also represent this division. However, when crossed with some of the key questions in the survey, the choice of specialisation does not seem to influence the results significantly.


*Figure 4. Two thirds of the students in this research project study arch/urb and there is a slight overweight of female students*

When asking the students about whether or not the relation between math lectures and exercises in Rhino/Grasshopper gave them a better understanding of form and curvatures, the answers were rather ambiguous. However, when crossing the answers with the question on preference in way of thinking, a tendency seemed to be revealed. As it is shown in Figure 5, students with a preference in mathematical/logical thinking clearly found the combination more fruitful in relation to their understanding of form than the students rating themselves as create/aesthetically oriented. 44 % of the mathematically oriented students answered that the combination *to a high degree* or *to a very high degree* gave them a better understanding. This number is significantly lower for the students with creative/aesthetic preference. The tendency is seen in the lower end of the bars in Figure 5. Only a few students could not identify themselves as any of the two categories, and these are not represented in the figure.

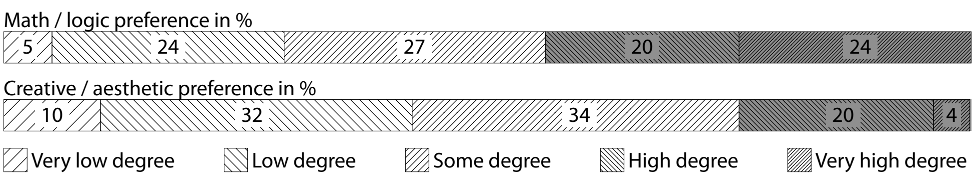


*Figure 5. Answers on whether or not the combination of math lectures and Grasshopper workshops improved the students understanding of form*

A plausible reasons for the tendency illustrated in Figure 5 could be the distribution of the students' preferences regarding modelling tools. In Figure 6 below, it is clear to see that students with preference for mathematical/logical thinking to a large extent prefer digital 3D modelling software to pen and paper or physical models. Based on this, it can be argued that it is typically students with an existing preference on digital tools that find the combination of math and Grasshopper exercises fruitful.

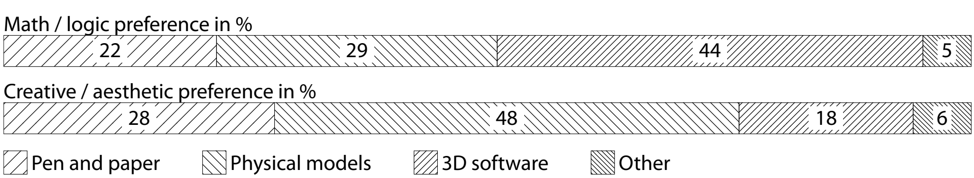


*Figure 6. Students' preferences on modelling tools combined with "thinking preference"*

The data does not clearly document this, but combining the insights from Figure 5 and Figure 6, it can be argued that it is the preference in digital tools rather than an actual improvement in understanding and working with form that drives the interest.

Regardless of what may drive the students to like or dislike the combination of Math lectures and Grasshopper exercises about form generation, most students seem to agree that they are not becoming better designers solely because of the gained competences in describing form through mathematical expressions. This is seen in Figure 7 below, where students – despite thinking preferences – tend to agree that they as a result of the course programme only to a *low* or *very low degree* becomes better at creating form.

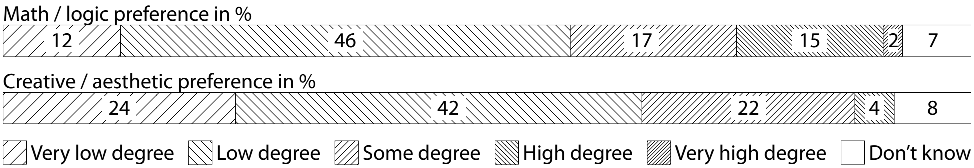


*Figure 7. It is a clear tendency that students do not see themselves as better designers after the Mathematics and Form course programme*

## 5 DISCUSSION AND CONCLUSION

This paper has presented the challenging dilemma of developing a design engineering curriculum that has to accommodate two distinct archetypes of students. The paper has furthermore described a specific course programme developed to cross over between the two distinct areas of *math* and *form* in an attempt to meet the interest of the two types of students. Through a survey, it has been investigated whether or not the combination of learning mathematics and algorithmic form generation improve the design students understanding of form, and the result of this survey will be discussed in this last section of the paper.

### 5.1 Answering the research question

As it has been showed in the previous section, the answer to the question about an improved understanding of form, points in two different directions depending on which type of students we ask. According to the gathered data, the mathematically oriented students implied that the combination gave them a better understanding of form, whereas the same point of view was significantly less distinct in the group of students seeing themselves as create/aesthetically oriented. However, both groups of students seemed to agree that the course did not improve their practical skills as designers, creating form. The students' clear distinction in their answers about *understanding form* and *creating form* indicate that they are quite well aware on *what* they have learned about form during the course, and perhaps also what kind of learning that this course format is probably *not* good at facilitating.

### 5.2 Learning about form through math or math through form

So, should we continue to combine distinct topics as math and form in our courses? After all, it only seemed to be the one group of students (the math/logically oriented students) that really benefited from the combination and ended up with a better understanding of form. Looking broadly at the results of the present study, the answer should probably be *yes*, as the most important learning from the data actually might be that students *do* learn differently due to their different preferences, and that teaching should accommodate learning about form in a range of different ways in order to reach all types of students in this cross-disciplinary field. The main perspective in this paper is "learning about form through math", but looking at the same course in a different way, the main perspective could have been "learning math through form." Looking at the students' experiences in that perspective, it is likely that the students benefiting from the use form to facilitate math learning would be the ones that are create/aesthetically oriented. However, this has not been investigated in this paper.

Returning to the discussion about teaching students in "form," it is clear that students to an increasing extent work with this area in virtual environments. It can therefore also be argued that form should be taught in a virtual environment: Just as we educate design students in understanding the logic, benefits, and limitations of traditional design tools like pen and paper, we aught to do the same in the virtual environment where the logic is not based on mathematical expressions and Boolean operation rather than three-point perspective and pen thicknesses. Whether such topics should be included in a course on basic math or a traditional design course – or a course combining the two areas like in the Mathematics and Form course – is difficult to say based on study presented in this paper. But it seems likely that topics such as *math* and *form* move closer together due to the increasing emphasis on software tools as an integrated part of the design practice.

### 5.3 Critique of results

Leaving the discussion about combining math and form for a while in order to take a critical look at the investigation itself, it is clear that the respondents rather positive towards their own learning outcomes from the course. It is very likely that the students actually gained a lot from the course when it comes to understanding and generating form through mathematical expressions, but the results could also be biased due to the fact that it was the students themselves that had to evaluate their own learning in the survey.

It is also likely that the students answer the questions more positively if they get the impression that it would benefit the investigation, even though the authors have not been involved in running the course. During the interview with the course coordinator and main lecturer, a slightly different picture of the students learning outcomes was presented. On the question about whether or not he think the combination of math and form benefits the learning outcome, he answers:

*"What has perhaps earlier been perceived as tough square-bashing now makes sense on an earlier state. But I have to say that the effort – to a large part of the students – is sporadic. And at some point they loose track."*

He continues to comment on the group of students in general:

*"I don't think that these students are a homogeneous group. Together, they form a highly varied group – which is good, I believe. But they also vary much when it comes to their perception of geometry and relation to mathematics."*

The comments from the course coordinator indicate that the students' own perception of their efforts and learning outputs may be biased to some point.

### 5.4 Concluding remarks and future research efforts

Referring to the title of the paper, it can be questioned whether or not the gap between math and form has been successfully bridged? According to the present research effort, it can be argued that the course programme "*Mathematics and Shape"* on the Architecture and Design bachelor education at Aalborg University is a thorough attempt in doing so. From the survey, it can also be argued that the students with a preference in logic/mathematical thinking have gained a better understanding of form as a result of the course. The gap, however, also refers to the diversity in the student group at cross-disciplinary educations such as the industrial design engineering programme. The results of this paper may therefore also act as a simple reminder of the fact that students have different learning preferences and perhaps more importantly: This should be reflected in the curriculum of the education.

Hopefully, this paper will serves as a starting point for a discussion on how we can plan and conduct courses at university level in order to facilitate learning for all types of students – regardless of learning preference.


## ACKNOWLEDGEMENT

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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# WHERE DESIGN AND ELECTRONICS MEET: INTEGRATE ELECTRONICS IN PRODUCT DESIGN

**Tommie VAREKAMP, Ianus KELLER and Jo GERAEDTS**
Delft University of Technology, Faculty of Industrial Design Engineering

**ABSTRACT**
In the last decade inexpensive digital electronic components have become accessible for the field of product design, making it possible to integrate electronics in all kinds of products. By using integrated electronics a product can differentiate from its competitors with a large variety of new functions and/or product behaviours. However at the same time the complexity of the product increases. Therefore a selection process is required that explores the added value and at the same time evaluates the feasibility of electronic technologies early in the design process. With a combination of user centred design and technical knowledge especially industrial designers seem to be well equipped for this selection process. Unfortunately evaluating the technical feasibility of integrated electronics is currently receiving too little attention in design education.
This paper presents the conclusions of a qualitative study in the working methods of professional design practice to gain insights in this early selection process. It shows industrial designers themselves possess limited technical knowledge of the electronic domain, but compensate this by communicating with external electronics experts early in the design process. Their communication is facilitated by the visualization skills of designers making it possible to talk about integrated electronics in a "designerly" way with little technical terminology. However this way of working also has its downsides, because it limits the exploration of different electronic systems and the ability of designers to design the product behaviour. By comparing the findings of this study with research on inter-disciplinary cooperation this paper proposes a starting point for design educations to empower designers to work with integrated electronics early in the design process

*Keywords: Product design, Integrated electronics, Design education, Inter-disciplinary cooperation*

## 1 INTRODUCTION
In the past few years the field of product design got a new set of materials to work with. ICT components that were first restricted to electronic devices such as computers are being integrated in an increasing variety of products. A development that is described in various paradigms such as ubiquitous computing [1] and the Internet of Things [2]. The integration of these electronic technologies enables products to collect, manipulate and share digital information resulting in many new possible functionalities. Furthermore integrated electronics has a large impact on the product behaviour making it possible to take into account or anticipate users emotional state, environmental factors [3], [4] or enhance the interaction with these products [5]. However transforming this large amount of new possibilities into feasible products with added value creates challenges at the start of the design process.

### 1.1 Differentiating with the use of integrated electronics
Besides the opportunities for totally new products this paper focuses on the impact of integrated electronics on existing products that (seemed to) have a fixed set of functions. Take for example the smart thermostat, figure 1 shows two thermostats that both fulfil the basic functionality of regulating heating, but use different integrated electronics to provide added value over "traditional" thermostats. Where the left thermostat 'Toon' focuses on data collection and visualization [6], the 'Nest' on the right offers automated adaptation of the product behaviour [7]. Especially when looking for opportunities to differentiate from competitors it is not clear at the start of the design process if, which

and how electronics should be integrated. Deciding which values to offer for end users and the selection of feasible electronic technologies is an iterative process where the outcome is not clear from the start, as is illustrated by the development of a third smart thermostat by Bosch [8]. This combination of exploring the added value and evaluating feasibility has a large impact on the direction of the design process and success of the final product. Industrial designers seem to be well equipped for a central role in this process with a combination of user centred design methods and technical knowledge.


*Figure 1. Two smart thermostats, the Toon (left) showing real time energy use and the Nest (right) analyzing user behaviour to automate the heating schedule.*

### 1.2 Challenge for design education

At the Technical University of Delft the faculty of Industrial Design Engineering (IDE) stresses the importance of combining user centred design and technical knowledge [9], [10]. However the technical knowledge is mainly focused on the mechanical domain [11]. Currently the attention for the domain of electronics and mechatronics is increasing in the curriculum, but the education on the feasibility of electronic technologies is still marginal.

The absence of technical feasibility can also be seen in design literature, which often focuses on a relevant but abstract level [12], [13] or on a more specific level emphasizes the importance of the product behaviour, but leaves out technical details [5]. Technical literature often starts from a very theoretical level [14], or focuses on people with a background in mechanical, electrical or software engineering [15], [16]. It is unrealistic to include the in-depth background knowledge of one or all of these fields in design education, but as a result it is difficult for industrial designers to find practical information sources in for design projects.

Without practical sources, judging the feasibility of electronics is already difficult, but early in the design process this is extra challenging, because technical criteria are vague or even unknown. Especially unknown unknowns, criteria that are overlooked and later in the design process turn out to be important, create pitfalls in the design process [17]. Therefore understanding what impacts feasibility and evaluating the feasibility are both important to achieve the added value of integrated electronics in the final product. By missing this crucial part in design educations it becomes difficult for industrial designers to get a grip on integrated electronics early in the design process.

When trying to improve this aspect of design education it is important to take into account the diverse nature of industrial design and consequently the limited time to cover background knowledge of all relevant fields. Therefore the research in this paper focused firstly on professional practice to get an overview of current working methods and identify what methods, tools and knowledge is relevant.

## 2 RESEARCH IN PROFESSIONAL PRACTICE

To gain insights in the process of exploring and evaluating integrated electronics a qualitative study has been conducted in professional practice. Preliminary interviews with several design professionals emphasized the importance of cooperating with electronics experts to judge the technical feasibility. Based on these interviews a framework is formulated that shows the steps industrial designers are expected to take when considering the integration of electronics (figure 2). Because the early design phase is vague designers are expected to detail integrated electronics to a certain extend before communication about technical criteria and feasibility is possible.

Based on the framework in (figure 2) three workshop sessions are held in design agencies, each with two participating design professionals. Using the design of a smart thermostat as example case the participating designers were asked to explain their way of working, methods and/or tools. During the workshops participants were specifically asked about their information sources to gain insights in their technical knowledge, and cooperation with electronics experts.

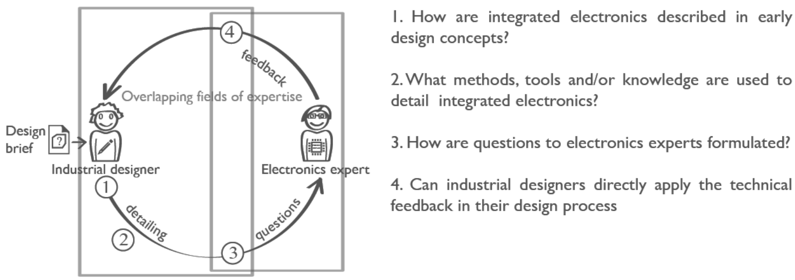


*Figure 2. Framework for working with integrated electronics, based on preliminary interviews with design professionals*

## 3 CURRENT WORKING METHODS AT DESIGN AGENCIES

The workshops in different design agencies showed clear similarities in the design process when considering the integration of electronics. However there is no standard approach and designers emphasized that the exact way of working depends heavily on the project brief. Besides several common actions, such as benchmarking with competitors, two aspects have a clear central role in all participating design agencies: use scenarios and knowledge from experience (figure 3). Visualizing use scenarios is done to specify functionalities, product behaviour, required components and known criteria. Making these use scenarios is an iterative process to explore different options and include as much details as possible of the (known) aspects that are involved.

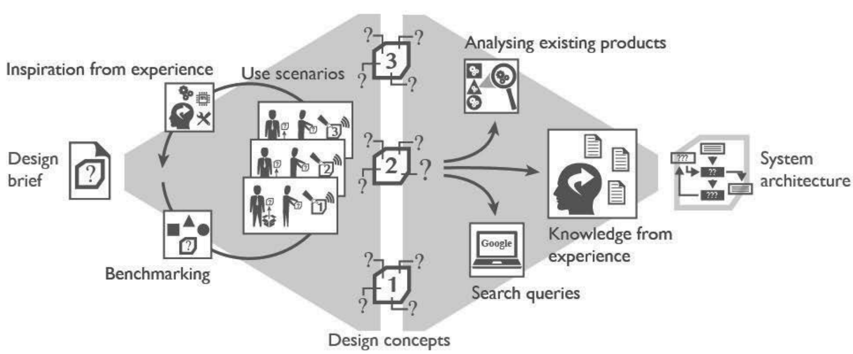


*Figure 3. The exploration and detailing phase of integrated electronics, showing the main role of use scenarios and knowledge from experience*

During the exploration process aspects that are uncertain and known to be important for the success of the product are specified. This results in one or more early design concepts with several uncertainties that have to be clarified in order to judge the technical feasibility. At this point the importance of knowledge from experience becomes evident. Again exact working methods differ between design agencies, but all industrial designers rely heavily on their own experience to identify and investigate uncertainties.

During the workshops several methods and tools were mentioned to gather more (technical) information about electronics needed to judge the feasibility. Internet queries using standard search engines, analyzing products with similar functions and small tests are all used to gather information. However when discussing these actions in detail it became clear the industrial designers need to have previous experience with a very similar situation to be able to apply the found information in a new design project. With the variety in design projects and electronic technologies encountering a very similar situation is rare, therefore the help of external electronics experts is often needed very early in the design process.

### 3.1 Communication with electronics experts

Ideally a schematic overview of the electronic technology is made when contacting external electronics experts. During the workshops each design agency showed their own kinds of visualizations, but they are essentially system architectures, showing the known electronic components as black boxes with their input and output. System architectures are mentioned as very useful because the in- and output can be based on use scenarios and can also be used by experts to further detail electronic technologies. In other words it is a visualization where the input from industrial designers and electronics experts comes together. But again industrial designers mentioned they have to be familiar with the electronic technology before they are able to visualize a system architecture. However this is not a threshold for industrial designers to contact external experts.
When discussing the cooperation with external electronics experts during the workshops it turned out most communication starts without any technical specifications or terminology. Electronics experts are contacted with small questions or vague ideas and much earlier then expected, which is shown in Figure 4. In these cases industrial designers use their use scenarios and other visualizations that show the functionalities, user interaction and context of use. Using this input electronics experts can identify requires components and technical criteria themselves and provide some general feedback. At first this is not enough to judge the technical feasibility, but electronics experts also help with further detailing of the electronic technology by thinking along with the designers about the criteria and alternatives. This makes it possible for industrial designers to evaluate the technical feasibility in close cooperation with electronics experts without possessing the required technical knowledge themselves. However this working method also has its downsides.

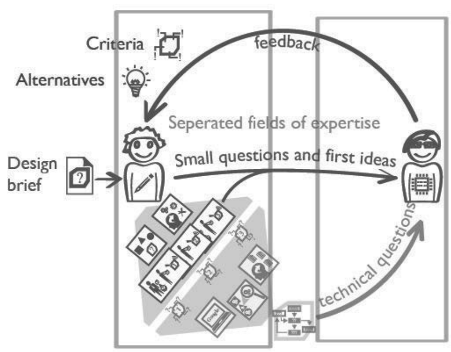


*Figure 4. The current working method of industrial designers showing that electronics experts are also contacted when no detailing is done by designers*

### 3.2 Limitations of the current working methods

In the current design practice industrial designers rely heavily on external experts to identify important uncertainties and criteria based on visualizations and communication in general terminology. As a result the required technical knowledge is not shared between designer and expert, but only the implications for a specific design project. This results in a slow and fragmented learning process for industrial designers where they only learn to apply a certain electronic technology in a specific design.
But the current way of working not only influences the learning process, but also the design process itself. All design agencies emphasized the time pressure in professional projects; making it important to reduce uncertainties as quickly as possible. In this situation the large dependence on knowledge from experience creates a strong incentive to only consider electronic technologies that have been used before. Then the change of missing important uncertainties and create unknown unknowns is smaller and the cooperation with external experts smoother, because (a start of) a system architecture can be made. This incentive to only apply what is applied before results a limitation of their solution scope. At the same time relying on external experts to specify technical criteria makes it difficult for

designers to influence the product behaviour in detail. Especially aspects related to the user experience are difficult to translate from interaction qualities and metaphors to technical criteria and difficult to communicate to electronics experts that have no experience with this "fuzzy side of electronics", as one participating designer called it. Therefore with their current working method industrial designers are not only limited in their ability to judge technical feasibility, but also in the exploration and detailing of integrated electronics and their added value.

## 4 DISCUSSION

The current working method in professional practice shows a very practical approach that enables designer to work with technologies that were not covered in their education. However the current limitations prevent designers to really explore and design integrated electronics. The field of mechatronics emphasizes its multidisciplinary character to be able to integrate electronics successfully [18], but as mentioned in chapter 1.2 the role of industrial designers is underexposed, especially when cooperating with external experts. In a recent research Guido Stompff specifically focused on the role designers have in successful cooperation within multidisciplinary teams [19], which provides some interesting starting points for improvements.

Guido Stompff identified a facilitating role of designers in multidisciplinary cooperation by letting different experts reflect on their impact on the intended final product with the use of boundary objects and physical meetings. Boundary objects are visualizations wherein multiple experts can provide their input, identify criteria and see the relations between their separated fields of expertise [19]. In the communication with external experts a system architecture can fulfil this function, but this requires the designer to be aware of the involved components, at least on a general level.

By using these boundary objects in meetings a dialogue between experts can be created where uncertainties and criteria's are identified that experts would not consider on their own [19]. The current cooperation with external experts on the other hand is largely based on the initiative of the designer to ask questions and response of electronic expert based on interpreting visualizations and general terminology. To decrease the change that electronic experts miss technical criteria because they are not asked or specified, industrial designers should be aware about uncertainties that could be important for different kinds of electronics. Again this is knowledge on a general level that can be useful without the required background knowledge to solve these uncertainties.

Compared with designers that work within multidisciplinary teams, the cooperation with external experts requires designers to step more outside their own field of expertise. This requires an increase in knowledge about electronics, not necessarily to do the work of electronics experts, but to facilitate the cooperation. By taking this idea as a starting point we think design education can provide a relevant basis of knowledge on a general level while taking into account the limited time for each field in a diverse study as industrial design engineering.

## 5 CONCLUSIONS

In design projects where the integration of electronics is considered, the working methods of industrial designers from different design agencies have large similarities. Industrial designers start from the perspective of the user to explore the possible added value of electronic technologies. However to judge the feasibility of integrated electronics the technical knowledge of industrial designers is not sufficient. Instead industrial designers rely on communication with external electronics experts early in the design process.

To be able to discuss integrated electronics when technical criteria are not yet clear the visualizations skills and previous experiences of industrial designers are very important. With visualizations that show the user interaction and context of use it is possible for electronics experts to derive technical criteria and think along with designers. However this working method results in a large dependency on external experts and creates a fragmented and slow learning process for industrial designers making it difficult to check if important aspects being overlooked that can result in unknown unknowns. Furthermore the large dependency on previous experience in combination with the time pressure in professional practice creates a strong incentive to only consider technologies that are applied before, limiting the solution scope of industrial designers. Therefore the current working method not only limits the ability of industrial designers to evaluate technical feasibility, but also limits the exploration of possible integrated electronics and their added values for users.

A practical way for design educations to improve the current working situation is to focus on a knowledge base about electronics that improves the communication with external experts. Especially the components, criteria and uncertainties of different kinds of electronic systems that are relevant for the technical feasibility. In detail this differs for each design project, but being aware of these aspects on a general level forms the starting point for an improved cooperation with electronics experts about feasibility and product behaviour.

## 6 RECOMMENDATIONS FOR FURTHER RESEARCH

This paper provides the basis for a practical approach in education that helps industrial designers to get a grip on the feasibility of integrated electronics. The educated general knowledge could work as a framework wherein designers can place newly learned knowledge and thereby decrease the current fragmented learning process. To develop this framework it would be very interesting to get insights on this topic from the opposite viewpoint; how do electronics experts see the cooperation with industrial designers? By combining the input from different experts the framework can be substantiated.

Looking further ahead this framework should form a combination with design methods and tools that facilitate communication with experts that goes further then feasibility. By combining this basic level of knowledge with methods such as experiential prototyping, the goal should be to empower industrial designers to change from integrating electronics to: designing integrated electronics, its product behaviour and influence on user experience.

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# TEACHING DIGITAL TECHNOLOGIES IN INDUSTRIAL/PRODUCT DESIGN COURSES IN PORTUGAL

**Ana Cristina DIAS, Rita ASSOREIRA ALMENDRA and Fernando MOREIRA DA SILVA**
Faculty of Architecture – University of Lisbon | CIAUD

**ABSTRACT**
In full 21st century and living in a digital age, technology advancements have led to the development and use of digital media for product design projects' support. It starts with education and training, making students to contact and learn tools and methods of computer aided design (CAD). Believing that the level of digital technologies knowledge to design and representation is one of the basic requirements to get a position, and sometimes it makes the difference in choice requisites, this study presents the results of a critical diagnosis about the presence of 'informatics contents' applied to design in the academic curricula of industrial/product design in Portugal. As part of a PhD research focused on product design curricula's adequacy to business challenges, this study aims to demonstrate how important is to keep up with the fast technological development, increasing the professional perspectives for design students. Editing/treatment of image and sound, printing technologies and multimedia communication are some of the significant contents covered by those courses. Based on the gathering and interpretation of several Portuguese design education curricula for undergraduate and master degree programmes. It appears that the introduction of the principles and practices of digital tools and methods are transmitted early in the education process. Especially on undergraduate courses, contributing to a better preparation of the design students to the market and its demands and challenges.

*Keywords: Design education; product design; digital and technological contents*

## 1 INDUSTRIAL DESIGNER'S SKILLS: THE PROFESSIONAL PERSPECTIVES

In a period of significant change, design education and training should anticipate the business demands and provide the development of adequate professional skills. It starts with the understanding of the professional perspectives about the designer's profile.

According to Gomes [1] who studied the designer competencies profile facing the emerging market, one can assess it according to two approaches – the personal training (behavioural characteristics that depends of the tacit knowledge) and the professional qualification. Focusing on the second approach, we can find transversal competencies (such as ethical values, responsibility, dynamism, capacity to take initiative, creativity, entrepreneurial and innovation) and specific competencies that depend of the sub-area of design. Specifically on industrial design expertise (also referred as product design) the competences integrate the domain of specialized software for 2D and 3D visualization, the realization of models, the knowledge about the user/customer, the ability to design spaces and equipment, objects and artefacts appropriated for a defined target group [2] [3].

However, design education needs to be reviewed and updated periodically. With the continuous and rapid transformations of new technology and the product development process, what is teach today will be out-of-date in five years, i.e. the skills that students are learning in schools today will be out-of-date when they get employed [4]. So, this leads to a fundamental question on which we must reflect: how can industrial designers adjust and update their competencies to be competent for the emergent jobs?

## 2 EDUCATING DESIGNERS FOR DIGITAL TECHNOLOGIES

### 2.1 Bridging the sketches by hand with CAD and digital design

It is known that a good interface between education and business is a necessity and a prevailing concern. It is also known that the reformulation of academic curricula, based on the work of researchers, is a constant in any design course [5]. Living in a digital age, the level of digital technologies knowledge to design and representation is one of the basic requirements to get a position, and sometimes it makes the difference in choice requisites, because the main focus of concern and requirement for the business sector is currently the performance of the designers in the field of technology combined with new technical skills [3] [4] [5]. So, if the student's familiarity with the computer aided design (CAD) systems increases his/her professional perspectives, the tools and methods of CAD are also the first step to break with conventional drawing on paper. However, this has little effect on the initial phase of the design process [6], being assumed as fundamental at more advanced stages of the conceptual development. It is with sketching that the creative process starts, because innovation is controlled and limited by software [7]. It is through sketching that mental activity is available for the systematization of information, for studying the coherence of form, to generate the best technical solution and, consequently, for creativity [7]. Although drawing may seems having an abstract feature, it is strictly necessary the establishment that designer do with his/her drawings, through different scriber tools [7], because "sketches not only serve as the descriptive tool for designers to record what is within their minds but it is also a tool for designers to reinterpret the sketches previously made and to reorganize their concepts" [8] [9]. Sketching is not only the tool to register the first ideas but the tool to verify various hypothesis, being known as the procedure to express, interpret, criticize, evaluate and clearly define the projective intent. It should remain inseparable of training and professional practice, mainly by incorporating its critical dimension in the conceptual design process [9] [10]. So, the introduction of new technologies as bi and tri-dimensional tools of representation, through specialized software, emerge as auxiliaries and facilitators of the conceptual design process [7]. The new technologies proliferate in contemporary society compared to the traditional paper support [11]. However, and although the systems of representation in the creative process are increasingly computerized, Sketching by hand can never fall into disuse because it is the direct tool for the representation of ideas, which usually emerge random and amorphous during the design of a product [9]. In fact, making use of digital tools facilitate the designer's everyday tasks, it saves time [10] , but also allows to design with rigor and detail which most of the times is hard to be done by hand drawing [12]. The use of drawing software also allows error detection and a quick translation to industrial production systems in the shortest possible time [12] [13]. The freedom in the creative process provided by sketching must be complemented and reinforced by the use of digital tools that make easier to produce detailed and precise drawings.

### 2.2 From CAD to…

The software for computer aided design (CAD) is framed as graphic tools supported by computer technology whose objective is the development of projects with high level of accuracy that enable control of the development process [15]. Some information related to sizing (thickness, weight, concavities, convexities) are generated, thus enabling rapid presentation of alternatives (colour changes, surfaces, textures, decorative elements) and photorealistic images with renderings (these possibilities depend on the software used and installed computing capacity). So, CAD systems act as auxiliary tools in the creation process, making it possible to display three-dimensional (rotation) and parameterized design (construction with mathematical data) object and as a tool to aid preparation of technical drawings [14].

Resorting to Rapid Prototyping process, which starts in the CAD system (where the product is designed in the virtual three-dimensional form, with output files in STL format - stereolitography) followed by sending the data to a CAM (that selects the best cutting tools for a particular material and specifies the appropriate speed of operation, optimizing the process) [14] today a product does not need to be manufactured to be exposed to the consumer [13]. Everything can be done on specific software and tested by the target audience to see if this product is ready for market or not [13]. With the advancement in the quality of designs, the decrease time and costs and increase of the overall productivity, the development team can have a feedback from user/consumer. So, after knowing their

reaction, the development team will be able to adapt the product to market needs, in the shortest possible time [13].
Marsh e Arthur [16] defend that the CAD and CAM learning process, similarly to other disciplines in the design area, must be done having as a departure point the debate, the exchange of ideas and the group work. This enhances students' critical awareness as well as boosts their knowledge and skills like management and communication, necessary to function productively in large interdisciplinary teams and organizational structures. Thus, the designer's main function is to use the available technology effectively as a facilitator and innovator way to materialize products, increasing the freedom of the creative process [14].
More important than which software is learned, is the designer's ability to do 3D drawing renderings and to make sophisticated models, and because educators cannot predict the possibilities of technology, industrial designers will always need to adjust and update their competencies [4].

## 3 DIGITAL TECHNOLOGIES IN INDUSTRIAL DESIGN HIGHER EDUCATION – PORTUGAL AS CASE STUDY

In Portugal, currently, industrial design higher education offers 29 undergraduate courses and 22 master courses. Integrating our PhD research, we mapped those courses and made the gathering and interpretation of their official curricula (publicly available in their own webpage) to verify the presence of digital technologies contents.
In order to make the curriculum benchmarking it were created two analysis grids (one for undergraduate and another for the master) about the courses which offer digital technologies curricular units (CU). Those grids were organized into four sections: i) identification of the institution of higher education (based on mapping previously done); ii) identification of the CU; iii) the semester it occurs; and iv) the percentage of ECTS of these CU(s) facing the total academic degree ECTS.
As it can be seen in Figure 1, all of the undergraduate courses offer digital technology contents. Nevertheless, this existence is reduced when we compare the curricular unit ECTS with the whole ECTS of the course (180 ECTS = 100%). Table 1 shows that the prevalence of digital technologies curricular units varies between 3.3% and 30.6%, with an average of 13.3%. These approaches occur all the semesters, in a balanced manner, however, it's more evident during the second year of the undergraduate programs.

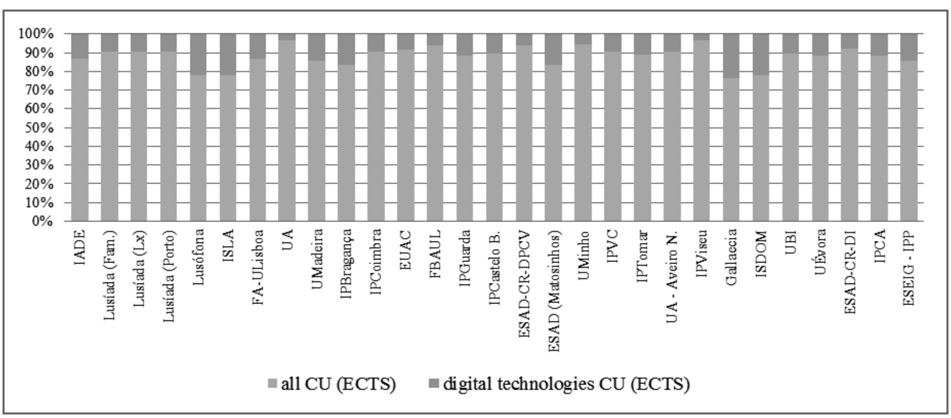


*Figure 1. The existence of digital technologies CU in industrial design undergraduate programs*

*Table 1. The existence of digital technologies CU in industrial design undergraduate programs*

| IHE \| DISTRICT | SEMESTER / ECTS | | | | | | | | | % |
|---|---|---|---|---|---|---|---|---|---|---|
| IADE \| Lisboa | 1st | 3rd | 3rd | 4th | 5th | 6th | | | | 15% |
| | 3 | 3 | 3 | 6 | 6 | 6 | | | | |
| Lusíada (Fam.) \| Braga | 1st | 2nd | 3rd | 4th | 5th | 5th | 6th | | | 13.3% |
| | 3 | 3 | 3 | 3 | 3 | 6 | 3 | | | |
| Lusíada (Lx) \| Lisboa | 1st | 2nd | 3rd | 4th | 5th | 5th | 6th | | | 13.3% |
| | 3 | 3 | 3 | 3 | 3 | 6 | 3 | | | |
| Lusíada (Porto) \| Porto | 1st | 2nd | 3rd | 4th | 5th | 5th | 6th | | | 13.3% |
| | 3 | 3 | 3 | 3 | 3 | 6 | 3 | | | |
| Lusófona \| Lisboa | 1st | 1st | 2nd | 2nd | 3rd | 4th | 5th | 5th | 6th | 27.8% |
| | 6 | 4 | 6 | 4 | 6 | 6 | 6 | 6 | 6 | |
| ISLA \| Lisboa | 1st | 2nd | 3rd | 3rd | 3rd | 4th | 5th | 6th | 6th | 28.3% |
| | 6 | 6 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | |
| FA-Ulisboa \| Lisboa | 2nd | 3rd | 4th | 5th | 5th | 6th | | | | 17.8% |
| | 3,5 | 7 | 7 | 7 | 3,5 | 7 | | | | |
| UA \| Aveiro | 4th | 5th | | | | | | | | 3.3% |
| | 2 | 4 | | | | | | | | |
| Umadeira \| Madeira | 1st | 1st | 3rd | 4th | | | | | | 16.7% |
| | 7,5 | 7,5 | 7,5 | 7,5 | | | | | | |
| IPBragança \| Bragança | 1st 2nd | 3rd 4th | 3rd 4th | 5th 6th | | | | | | 20% |
| | 10 | 6 | 10 | 10 | | | | | | |
| IPCoimbra \| Coimbra | 1st | 2nd | 3rd | 4th | | | | | | 10% |
| | 6 | 6 | 3 | 3 | | | | | | |
| EUAC \| Coimbra | 1st | 2nd | 3rd | 4th | | | | | | 8.9% |
| | 4 | 4 | 4 | 4 | | | | | | |
| FBAUL \| Lisboa | 3rd | 4th | | | | | | | | 6.7% |
| | 6 | 6 | | | | | | | | |
| IPGuarda \| Guarda | 1st | 2nd | 4th | 5th | 5th | | | | | 13.3% |
| | 5 | 5 | 5 | 4 | 5 | | | | | |
| IPCastelo B. \| Castelo Branco | 1st | 2nd | 3rd | 4th | 5th | | | | | 11.7% |
| | 5 | 4 | 4 | 4 | 4 | | | | | |
| ESAD-CR-DPCV \| Leiria | 3rd | 4th | | | | | | | | 6.7% |
| | 6 | 6 | | | | | | | | |
| ESAD (Matosinhos) \| Porto | 1st 2nd | 1st 2nd | 3rd 4th | 5th 6th | | | | | | 20% |
| | 9 | 9 | 6 | 9 | | | | | | |
| Uminho \| Braga | 3rd | 4th | | | | | | | | 5.6% |
| | 5 | 5 | | | | | | | | |
| IPVC \| Viana do castelo | 5th | 6th | 6th | | | | | | | 10% |
| | 6 | 6 | 6 | | | | | | | |
| IPTomar \| Tomar | 2nd | 3rd | 4th | 4th | | | | | | 12.2% |
| | 5 | 6 | 6 | 5 | | | | | | |
| UA - Aveiro N. \| Aveiro | 1st | 3rd | 4th | | | | | | | 10% |
| | 6 | 6 | 6 | | | | | | | |
| IPViseu \| Viseu | 1st | | | | | | | | | 3.3% |
| | 6 | | | | | | | | | |
| Gallaecia \| Viana do Castelo | 1st | 2nd | 3rd | 3rd | 4th | 4th | 5th | 5th | 6th | 30.6% |
| | 8 | 8 | 9 | 3 | 8 | 2 | 7 | 3 | 7 | |
| ISDOM \| Leiria | 1st | 1st | 2nd | 2nd | 3rd | 4th | 5th | 5th | 6th | 27.8% |
| | 6 | 4 | 6 | 4 | 6 | 6 | 6 | 6 | 6 | |
| UBI \| Castelo Branco | 1st | 2nd | 3rd | 3rd | | | | | | 11.7% |
| | 6 | 6 | 6 | 3 | | | | | | |
| Uévora \| Évora | 1st | 1st | 1st | 2nd | 2nd | 2nd | 4th | | | 13.3% |
| | 5 | 5 | 2 | 4 | 5 | 2 | 1 | | | |
| ESAD-CR-DI \| Leiria | 3rd | 4th | 4th | | | | | | | 8.3% |
| | 6 | 6 | 3 | | | | | | | |
| IPCA \| Braga | 3rd | 4th | 5th | 5th | | | | | | 13.3% |
| | 6 | 6 | 6 | 6 | | | | | | |
| ESEIG – IPP \| Porto | 1st | 2nd | 4th | 5th | 6th | | | | | 16.7% |
| | 6 | 6 | 6 | 6 | 6 | | | | | |

As it can be seen in Figure 2, fifteen of the master courses offer digital technology contents. Nevertheless, this existence is reduced when we compare the curricular unit ECTS with the whole ECTS of the program (120 ECTS = 100%). Table 2 shows that the presence of these curricular units varies between 4.2% and 19.2%, with an average of 9.4%. These approaches occur mainly on the first year of the master programs.

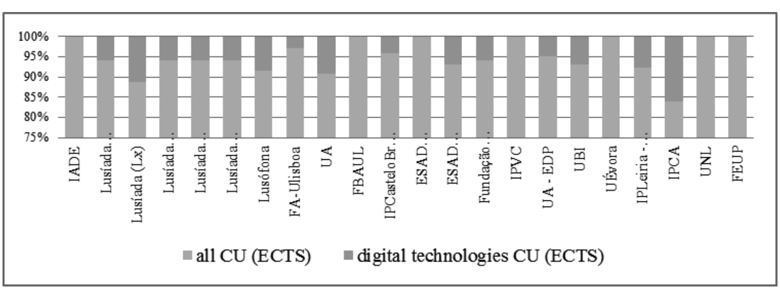


*Figure 2. The existence of digital technologies CU in industrial design master programs*

*Table 2. The existence of digital technologies CU in industrial design master programs*

| IHE \| DISTRICT | SEMESTER / ECTS | | | | % |
|---|---|---|---|---|---|
| Lusíada (Fam.) \| Braga | 1st | 2nd | | | 6.25% |
| | 3,75 | 3,75 | | | |
| Lusíada (Lx) \| Lisboa | 1st | 2nd | | | 12.5 |
| | 7,5 | 7,5 | | | |
| Lusíada (Lx) – DP \| Lisboa | 1st | 2nd | | | 6.25% |
| | 3,75 | 3,75 | | | |
| Lusíada (Porto) – DP \| Porto | 1st | 2nd | | | 6.25% |
| | 3,75 | 3,75 | | | |
| Lusíada (Porto) – DIE \| Porto | 1st | | | | 6.25% |
| | 7,5 | | | | |
| Lusófona \| Lisboa | 1st | 2nd | | | 9.2% |
| | 5 | 6 | | | |
| FA-Ulisboa \| Lisboa | 3rd | | | | 2.9% |
| | 3,5 | | | | |
| UA\| Aveiro | 1st | | | | 10% |
| | 6 | | | | |
| IPCastelo B. \| Castelo Branco | 2nd | | | | 4.2% |
| | 5 | | | | |
| ESAD (Matosinhos) \| Porto | 1st \| 2nd | | | | 7.5% |
| | 9 | | | | |
| Fundação RES \| Lisboa | 1st | 2nd | 3rd | | 6.25% |
| | 3 | 2 | 2,5 | | |
| UA – EDP \| Aveiro | 1st | | | | 5% |
| | 6 | | | | |
| UBI \| Castelo Branco | 1st | 2nd | | | 7.5% |
| | 3 | 6 | | | |
| IPLeiria – ESTG \| Leiria | 1st | 2nd | | | 8.3% |
| | 5 | 5 | | | |
| IPCA \| Braga | 1st | 1st | 2nd | 2nd | 19.2% |
| | 5 | 7 | 5 | 6 | |

About the CU program contents, they are based on three main approaches: i) creation and editing/treatment of images (such as the ability to do bi and tri-dimensional representations, i.e. enabling to do technical and vector drawings, to make sophisticated models and to do 3D drawing renderings), ii) to prepare it for 2D and 3D printing tools (enabling the use of Rapid Prototyping and Computer Aided Manufacturing) and iii) introduction of multimedia tools (audio and video). This allows not only the representation and manipulation of images, but it also facilitates the presentation/communication of the created objects. The first is evident in both education levels but there is an emphasis on the second and the third approach on the master degrees. Concerning the CU program goals, they mainly focus on the understanding of the relationship between analogue and digital design expression, through the proper use of the digital tools and software and comprehension of its possibilities.

## 4 DISCUSSION AND RESULTS

This study aims to identify the given importance of teaching digital technologies in Design Education system, keeping up with the fast technological development. Based on the gathering and interpretation of industrial/product design undergraduate and master Portuguese curricula, it turns out that the contact and learning of tools and methods of computer aided design (CAD) occurs early in the formation process, especially on undergraduate courses, and with a specialized approach to the production (CAM) and prototyping on master courses. Those courses that address digital technologies issues (tools and methods of computer aided design) must be used as support of Design Education, specially to the processes of collaborative and participatory design, promoting the interdisciplinary nature of the course, establishing the link between pedagogical knowledge and educational practice, exercising the exchange knowledge and build new concepts [17]. Focus on the bi and tri-dimensional representation, manipulation of images and presentation of the objects created, every Portuguese undergraduate courses offer digital technologies learning tools. In turn, this approach with the emphasis on Rapid Prototyping and CAM is more evident on the master levels.

Believing that the knowledge about CAD and CAM emancipates the designer, allowing him to assist the sketching (solving technical problems that sketching cannot detect) and to present their own projects to the client without having to be prototyped, the new systems of representation enable the increasing detail avoiding faults in the production process; thereby reducing waste and contributing to more sustainable product development [14].

In a period of significant change and living in a digital age where new technologies proliferate in contemporary society, design education and training should anticipate the business demands and provide the development of adequate professional skills, instilling in students the knowledge concerning digital media for product design project's support. That domain contributes to a better preparation of the design students to the market and its demands and challenges.

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# 3D CAD AND MENTAL SCALING IN THE PRODUCT DESIGN PROCESS: EXPLORING THE CREATIVITY POTENTIAL IN DESIGN EDUCATION

**Harald SKULBERG**
Institute of Design, The Oslo School of Architecture and Design (AHO), Norway

**ABSTRACT**
This paper explores the potential of using technology as a tool for creativity in design education. The gap between research and practice in the design field requires a stronger emphasis on research on design methodologies, and investigating the influence of technology in this context seems appropriate. In particular, this paper explores the relation between the use of parametric Computer-Aided Design (i.e. CAD) software and mental scaling - or mental elasticity. Mental scaling describes the ability to mentally fluctuate between divergent and convergent thinking through the design process. This is a case study where a group of industrial design students without previous experience with using this software were asked to document their own physical model during an assignment by building their own virtual 3D model. Through the use of photo documentation, observations and a written questionnaire, this study explains how CAD may constitute a catalyst for mental scaling by turning the initial documentation process into an extended design process through added iterations.

*Keywords: Design methodology, Computer-Aided Design, mental scaling, virtual 3D model, case study*

## 1 INTRODUCTION

As the design field moves towards immaterial media and conceptualization, we acknowledge that a stronger emphasis on research on design methods is required, and this paper aims at bridging the gap between research and practice within the design field. Due to demands from industry, the teaching and utilization of digital media have become increasingly essential in academia. The versatility of recent computer aided design software has become an important asset for industrial designers and product designers in particular, as the use of CAD has become an essential skill for the development, optimization and documentation of solutions within products and systems. The development of effective design methods utilizing the creativity potential inherent in CAD is therefore highly relevant in design schools. The potential to use CAD not only as a construction tool but also as a creative and stimulating design tool for exploration should be exploited in a broader manner than experienced today, and this study aims at investigating this potential.

### 1.1 The scope and design case

The scope for this study is a design case introducing 3D CAD - SolidWorks (i.e. SW) - to a group of first year industrial design students at the foundation level of a Master program in industrial design. The design assignment was divided in two parts, where the first part -Physical model- was the foundation for the second part -3D CAD model. After going through basic introductory tutorials under competent supervision, the design students were asked to develop their own virtual 3D model. The two assignments were defined as follows:

- **Assignment Part 1, Physical model:** “Give shape to a new object to be made of wood, plastic or metal. Examine a formal question or formal challenge you find interesting in relation to the material's inherent properties. In addition to the selected main material you will use one additional material of the three materials mentioned. This will enable you to plan and solve a joining between two different materials in your object. Object’s maximum dimensions: Height 20 x Width 20 x Depth 20 cm”.

- **Assignment Part 2, 3D CAD model:** "Transform the formal properties observed in the artefact in part 1 into a virtual 3D model using SolidWorks. Develop and clarify the visual qualities observed in your artefact by exploring and utilizing the functional possibilities in the Solid Works software".

### 1.2 Research question and hypothesis

In this particular context, the term creativity is comprehended as the ability to transform and develop visual and formal qualities found in the physical object into a virtual 3D model by exploring and developing these qualities into an intelligible, aesthetical perception by building a 3D model on screen. Our research question is: How may CAD constitute a catalyst for mental scaling, by turning a documentation process into an extended design process through added iterations during the exploration of SolidWorks software? Our hypothesis is that even a parametric 3D software like SolidWorks - which often is considered as a rigid construction tool – can provide a relevant stimulus and thereby become a catalyst for mental scaling - or mental elasticity - during the design process.

### 1.3 The theory of mental scaling

From a pedagogical perspective, our strategy was to enable the students to understand how design evolves during successive phases of a design process. This was facilitated by encouraging the students to take a free-minded approach during the design exploration in part 1, in order to develop a conscious attitude and focus on aesthetical considerations as a foundation for further exploration and in part 2.
Parallel to this strategy Lawson [1] refers to the Markus / Maver map of the design process by suggesting that each step of the process from outline proposals via scheme design to detail design demands a separate internal loop of analysis, synthesis, approval and decision. In many ways, this model matches our philosophy for this design case, as Lawson's model seems to reflect our idea of a holistic and generative approach that enables a structured product design process by integrating an internal loop of evaluation within each step of the design process. Following this line of thinking, mental elasticity -or mental scaling- describes the ability to actively fluctuate between divergent and convergent thinking, enabling mental iterations during a design process. The theory of mental scaling accords somehow with De Bonos [2] theory that discusses the power of lateral thinking in developing new ideas. According to Skulberg [3], mental scaling describes the ability to consciously navigate between abstraction through a holistic view and concretization through a fragmented view while exploring potential solutions during the solution search process. This holistic approach seems to be an essential capability for designers in order to attack a given problem from different angles through added iterations in order to explore and produce optimal solutions to a defined problem. When examining student capability parameters in this framework A-navigators tend to move towards abstraction (A) while C-navigators tend to move towards concretization (C). The theory of mental scaling has been a pedagogical and theoretical framework and inspiration for our study.

### 1.4 3D CAD

Two different modes of CAD modelling are dominant today; surface and solid modelling, of which Solid Works (i.e. SW) represents the latter, Stroud and Nagy [4]. In contrast to free-form surface modelling software like Alias, parametric CAD software is often considered as a tool basically for construction purposes, while free-form software is considered as a much more versatile tool enabling a more artistic and designerly approach. SolidWorks is a 3D mechanical CAD program that runs on a Microsoft Windows platform. It is a parasolid-based modeller, and utilizes a parametric feature-based approach to create models and assemblies. This software represents a sequential and generic approach where the operator must comply with specific pre-defined sequences of commands in order to build a three-dimensional body simulating physical mass and surface. Building a model in SolidWorks usually starts with a 2D sketch using geometry as a guideline for building the final three dimensional model. Three levels are important in order to understand the software structure: *Parameters* refer to constraints whose values determine the shape or geometry of the model or assembly, *Design intent* refers to how the creator of the part wants it to respond to changes and updates, while *Features* refer to the building blocks of the part.
On the general principles of building 3D form, Akner-Koler [5] argues that the 3D spacial matrix constitutes the fundamental context in which all visual components interact, using vertical, horizontal

and depth as basic dimensions. This is the reference of orientation for all positive and negative visual elements, and SW substantiates this principle for simulating mass and surface in 3D volumes.

### 1.5 Research methodology

Three different research tools were used in this study; Observations of the CAD sessions with tutoring in the computer lab, photo- and screen documentation, and a written questionnaire. Procedural steps through the process as well as the final results were accumulated, and the student's reflections were evaluated. It seems important to explain the relevance of choosing these tools. Firstly, personal observations when sitting close to the students at their computer produce an immediate impression on how the students proceed during the CAD assignment, and this knowledge has been fruitful for evaluating the individual on-going learning process as well as the final course evaluation. Secondly, photo documentation has been considered as the most effective medium in order to document each student's individual strategy to transfer the intrinsic properties and formal qualities of the physical model into the CAD medium. In this manner both the physical and the virtual model can be documented in one visual image. Thirdly, a written medium as the personal questionnaire was chosen in order to accumulate quantitative feedback on the student's use of CAD software. Answering the questionnaire was voluntary, and of the total group of 32 students, 23 students answered giving a response rate of 72, which seems satisfactorily representative sample. With 11 questions in the form, a total of 253 answers were given by the students. The questionnaire was specifically designed to define a set of individual student capability parameters as well as explaining how the students experience both advantages and disadvantages of using SW. The appearance of the physical and virtual models was compared, and the student's reflections after using the SW software were evaluated. One interesting aspect of investigating how the CAD software may constitute a catalyst for iterations is why there often is a visual difference between the appearance of the physical model and the virtual model, and why and how this difference builds. Our experience indicates that these differences appear to be an indicator of the fact that mental scaling actually has happened, and this has been the motivation for comparing the appearance of the physical and the virtual model.

## 2 VISUALIZATION TOOLS

Similar to a typical ideation process starting with two-dimensional sketches, SW also has the 2D sketch as a starting point for building the final three-dimensional model on screen. Olofsson [6] distinguishes between investigative, exploratory, explanatory and persuasive sketches. All these different four media are comparable to the equivalent levels of 3D physical models, represented by mock-ups, shape and form models, functional models, show models and final prototypes, according to Saeter, Solberg, Sigurjónson, Boks [7]. In the same way, these different media represent comparable levels on the mental scale -or clarity scale- as they all relate to a final completion representing an optimal solution and they are accordingly observed both in physical models and in 3D CAD. In practice, the student's final CAD model could either be foundation for a new iteration going back to a round of making a new refined physical model, or directly to rapid prototyping printed from a CAD-file, Filippi [8], which then would be useful to tangibly evaluate various physical solution concepts.

## 3 THE STUDY

The observations of students and teaching assistants at work in the computer lab together with photo documentation and a written questionnaire produced an interesting body of insights and reflections. During CAD sessions (Figure 1) the exploration of software functionality is carried out, processing and organizing visual information from the artefact -seen on the tables- into a virtual CAD model.

*Figure 1. CAD sessions utilizing SolidWorks software in the computer lab, based on artefacts seen on the tables*

When observing students during SolidWorks sessions, the act of switching between component level and assembly level, as well as zooming between render and extreme detail level, seems to initiate the student's mental elasticity, commuting from one mental level to another. In order to document the process of transforming a physical model into a virtual model, one particular student case (see Figure 2) exemplifies this process through a screenshot displaying the appearance of the new virtual object.

*Figure 2. Exploration of software functionality using SolidWorks Motion*

In the process of freely rotating the model on the screen, functionality in SolidWorks Motion is utilized. This is a virtual prototyping tool that provides motion simulation capabilities to ensure that the design actually works properly. However, we see that many of the students face challenges when translating the spatial information observed in the physical model, through parametric conversion in SW without losing the object's distinctiveness or subtle aesthetical character during the transformation process. The use of *Surface*, *Body* and *Coordinate* functions in SW enable quick manipulation of the object's structure, and these functions generate highly effective form modification abilities. Our observations also indicate that moving the point of view through rotation, zooming and equivalent modes seem to stimulate the student's imagination in terms of discovering a multitude of new form possibilities not previously revealed.

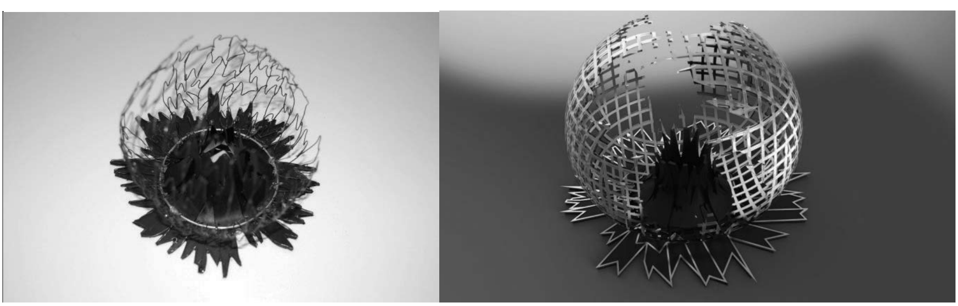

*Figure 3. A comparison between a physical model and a final CAD model*

Figure 3 shows how the irregular and unclear structure of a physical model (left) has been transformed into a new and much more precise geometrical structure (right) where the vertical rotation axis has been an important starting point for the form generation. As the pictured student expressed, the absence of formal clarity was a major problem with the physical model. The final result demonstrates the intention of making a precise, intelligible and easily recognizable form, however the formal translation has required distinctive alterations in component and material appearance.

While being a parametric CAD software, SW typically contributes towards a visual order and formal clarity in the 3D model, and this process often results in an aesthetical clarity by redefining the model's aesthetical expression, as the operator is forced to comply with the parametric rigidity of the software. As an example, several of the handmade models consist of complex, irregular hand-made body structures, and imperfections like joints consisting of glue or screws are present. These irregularities are erased in the virtual model, enabling a simpler and cleaner geometry which contributes to a stronger visual comprehension.

*Table 1. The questionnaire*

| Questionnaire: 3D CAD and mental scaling | Do not agree | Partly agree | Quit agree | Totally agree |
|---|---|---|---|---|
| 1. As a person I like best to work conceptually, I like working visionary with big visions, thoughts and issues, not details. | 5 | 8 | 8 | 1 |
| 2. As a person I like best to work concretely with specific things like drawings or physical models, often on a detailed level. | 0 | 4 | 7 | 12 |
| 3. When I work with hand drawings I like best to create rough, quick sketches. | 3 | 6 | 7 | 7 |
| 4. When I work with hand drawings I like best to work with precise lines. | 3 | 8 | 8 | 4 |
| 5. I feel that SolidWorks gives me many new solution possibilities because I discover new features or solution variants that I was not previously aware of. | 2 | 9 | 11 | 1 |
| 6. When I work with SolidWorks, I discover new design possibilities that I put into the solution along the way, and that makes the solution better. | 3 | 14 | 5 | 1 |
| 7. I find that working with SolidWorks limits my solution possibilities. | 6 | 7 | 10 | 0 |
| 8. Working with a tool like SolidWorks has a stimulating effect on me. | 0 | 5 | 15 | 2 |
| 9. I feel that I have discovered so many new design opportunities after after working with SW, it had been helpful with another round of hand drawn sketches and sketch models before any final solution drawn in SW. | 5 | 8 | 7 | 2 |
| 10. The following functions or features in SolidWorks help strengthen my design process (summarized): • More insight into the component structure • Good navigation • Precision & realism • Testing surfaces and textures • One can easily go back and change parameters • Opportunity to test many solutions quickly • Something unexpected happens which can be utilized in the design solution | | | | |
| 11. The following functions or features in SolidWorks weaken my design process (summarized): • It seems to be a complicated program to learn • Basically the functional aspects comes into focus • Hard to learn without a geometric affinity | | | | |

### 3.1 Focus areas and findings

The questionnaire constitutes three main focus areas: Q1-Q4 determines the distribution of personal student capabilities between A- and C-navigators in the group. Q5-Q9 assesses how SW stimulates towards added iterations and mental scaling. Q10-Q11 gives a qualitative feedback on how the students subjectively experience strengths and weaknesses of functions and features in the software. When assessed holistically as a group, the answers 1-4 indicate a tendency towards C-navigation among the majority of students. The highest individual score in the questionnaire is found in question 8, where 15 of the total of 23 students confirmed that Solid Works has a stimulating effect. Question 5 supports this attitude. Conversely, question 7 indicates that a significant number of students find that SW limits their solutions. The summarization of Q10 indicates that SW stimulates cross-level navigation, and the freedom to change parameters in an opportunistic manner is highly appreciated.

### 3.2 Mental fluctuation scale

In order to convey the complexity of mental scaling, we found it fruitful to develop a chart to describe the relation between mental iterations, solution space and software- or form generative limitations. Figure 4 describes a principal and simplified picture of how a typical mental scaling process is observed during the SW sessions, producing mental fluctuations between level A – holistic structure, and level C – detailed component design. As an example, the shaded area at point A3 will typically represent the point where the student recognizes how a search for solution on too abstract or holistic level exceeds software limitations or the form generative framework, and the consequence will then be that an iteration starts to build by commuting back towards a more convergent search. On the opposite end of the mental fluctuation scale, point C3 will typically represent the point where the student explores too complex details on a fragmented level, by testing and challenging software functions through commands that are invalid and which the software is unable to process. The fluctuation between A- and C-level finally culminates with a detailed component design constituting the final assembly structure comprising all individual parts of the virtual object within the given solution space.

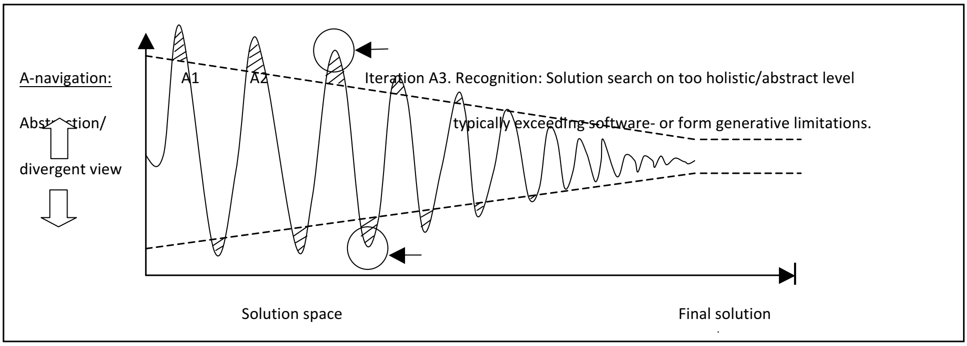


*Figure 4. Mental scaling during 3D CAD simulation in Solid Works*

## 4 CONCLUSION AND REFLECTIONS

Our hypothesis of SolidWorks constituting a catalyst for mental scaling is to some extent verified by our study. Given this particular scope, our study indicates that even a parametric 3D CAD software like Solid Works may stimulate an active fluctuation between abstraction through a divergent view and concretization through a convergent view. The mental fluctuation between a divergent exploration and convergent search for optimal solution is evidenced in the act of frequent switching between component level and assembly level, as well as zooming between render and extreme detail level. These mental fluctuations are driven by the need of a structural overview and a form generative insight, together with the intended exploration of components on a detailed level.

However, feedback from the students indicates that some of the students are challenge by what they describe as s software rigidity which limits their solution possibilities. It would be fruitful to study a larger number of design assignments in order to produce a more solid body of evidence, and this could be the next step for investigating this topic further. Furthermore, it would be advantageous to investigate the student's development in a long term.

The importance of rich media environment seems crucial for design teaching, as relevant tools are essential to the student's ability to investigate, explain and persuade effectively. The process of mental scaling initiates an active and explorative mindset, and the student cases indicate that CAD contributes as a creative tool for building formal imagination, not only as a construction tool. In general, the whole body of information produced by observation, photo documentation and answers given in the questionnaire has demonstrated the importance of evaluating learning outcomes from using powerful CAD tools like SW. This study has produced new and valuable insights on the utilization of relevant design tools, and how technology can contribute as a creative tool during the learning journey.

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# THE CHALLENGES OF DEVELOPING STYLING DNA DESIGN METHODOLOGIES FOR CAR DESIGN

**Shahriman ZAINAL ABIDIN[1,2], Azlan OTHMAN[1], Zafruddin SHAMSUDDIN[1], Zaidy SAMSUDIN[1] and Halim HASSAN[1]**
[1]Styling Department, Engineering Division, Perusahaan Otomobil Nasional Sdn Bhd (Proton), Malaysia
[2]Industrial Design Department, Universiti Teknologi MARA (UiTM), Malaysia

**ABSTRACT**
This paper discusses the challenges of developing 'Styling DNA' for car design. Existing theories, models and frameworks towards styling DNA are still fuzzy. Many car industries are still struggling with establishing a novel fact from styling DNA that can be used as a point of reference in supporting design concepts and specifications. There are two research directions towards styling DNA for car design in design methodologies; one is Algorithmic approach and the other is Manual approach. The example of Algorithmic approach is a Genetic Algorithm (GA). GA is an engineering analysis which is based on technology-driven direction. It evolved on the method of calculation which generates each item from some encoded form known as a chromosome that mutated to class new items. Meanwhile, the example of Manual approach is Human Visual Interaction (HVI). HVI refers to the design and implementation of product characters that people interact with. It is a study of design between people and products which are based on user-driven direction. For both approaches, either in academia or industries, it seems that the expectation is more on identifying the character traits and relative attributes of styling DNA a molecule that encodes the genetic instructions employed in the growth and aesthetics appealing of form that can be used as a unified point of reference.

*Keywords: Algorithmic, car design, manual, design methodologies, styling DNA*

## 1 INTRODUCTION

Recently, research on styling DNA has become important in car design. There is no clear definition about styling DNA which can be found in any English dictionaries. Here, a styling DNA is defined as a molecule that encodes the genetic instructions employed in the growth physical form or product. Even though, car design is being looked at as an innovative product and challenging discipline, it can be classified and positioning between the direction of technology-driven product and user-driven product [1]. Many researches on styling DNA towards car design have given focus on observing stylist in the design activities [2]. This is because stylist plays an important role in producing visual appearance towards aesthetics appealing of new products in the light of a general consideration of conceptual design [3]. Since aesthetics are common in the field of Art, it produces the reasons to gratify the concept such as: judgment, attitude, understanding, emotion, and value [4]. However, the most important part of styling is in the conceptual design phase, where there is a need to match the technical constraints or hard points such as identifying essential problems, establish function structures, search for principle solutions, combine and firm up into concept variants, and evaluate against technical and ergonomic criteria with the aesthetic intent of the stylist [5].
A common practice in car design, styling strategies consists: (1) Attention drawing: creation of visually appealing designs [3]; (2) Establishing recognition: brand and identity references [6]; and (3) Creation of symbolic meaning, e.g., metaphorical form [7].

## 2 ISSUES OF STYLING DNA

### 2.1 Genetic construction

The basic element of *Deoxyribonucleic acid* or DNA is the genome. In design, a genome is the "life form" whole set genes of DNA. In terms of definition, it is one haploid set of chromosomes with the

genes they contain. Broadly: the genetic material of an organism [8]. In the perspective of genetic terminology, the terms refer to a full set of chromosomes as well as all the inheritable traits of an organism. It contains all of the chromosomes in rank required to build and maintain that life form.
Most of the design research on genome explores the sequences, maps, chromosomes, assemblies and annotations. Even, the new car styling DNA shows potential disappearance from the current model and has the potential to bring us closer towards design aim [2]. Since, design is subjective in nature; there is a question about how can designers' establish the character traits of styling DNA for car design? Most exploratory research using experiments and analysis of data depended on syntax (structure) coding and pattern which derives from the studies. Since, the results can be too hypothetical, the researchers always argue in which context they should be explored in.

### 2.2 Contextual

Most of the research on styling DNA explores variables of studies either through natural resources or artificial intelligent information. However, in most cases, the studies focus varies dependent on what needs to be explored. Most car manufacturers refer to brand image and identity such as heritage and vehicle architecture (i.e., Volvo, Volkswagen, Range Rover, BMW, Mercedes, etc.). They maintain certain characters consistently in every production. Some car manufacturers imitate and reflects their vehicle architecture based on their competitors. This seems to be more market-driven in order to ensure the car is marketable.
Normally, in the context of marketing, there are several strategies which have been used by the car manufacturer as a strategic tool in order to establish brand image and identity. Among all: (1) Icon, Sign, and Symbol (i.e., Mini), (2) Object and Artifact (i.e., General Motor), (3) Furniture and Architecture (i.e., Volvo), (4) Art, Decoration, Culture, Heritage, and Costume (i.e., Alfa Romeo), and (5) Nature Resources (i.e., Volkswagen New Beetle). For example, in the development of company branding, Volvo claims that the Scandinavian elements embedded in cars designed by them [6]. This somehow evokes to the affective elements of styling DNA of the car between user and manufacturer.

### 2.3 Affective elements

Since car design is mapped and positioning between the parameter of user-driven product and technology-driven product, the elements of affective such as growth in feelings or emotional areas cannot be neglected. An affective element consists: attitudes, emotion and feelings that reflect product preferences [4]. There are several domain stages exist in affective models. This includes a domain of receiving, responding, valuing, organization, and characterization [9]. However, since design is subjective in nature, design is always being looked as private and individual. Therefore, the way designers' reason about form and the strategies employed in designing a "form" differs from designer to designer in the organization. It can be structured as well as emergent. From this parameter, we can see that, design can derive as problem solving (The problem-solving process considers the design activity as a problem to be defined and solved), normative (Normative rationales for action are based on evaluative judgments which justify beliefs, attitudes or actions regarding matters of knowledge, aesthetics or morality), synthesis-analysis (Synthesis-analysis is considered here as a compound activity, as it involves searching, exploration and discovery of design solutions, and composition and integration of these solutions), reflective (It is characterized as a reflective conversation with the materials whose basic structure-seeing-moving-seeing- is an interaction between designing and discovery), and hermeneutics (A hermeneutic model for designing is based on interpretative and intuitive processes, which are, firstly, driven by the inherent knowledge, past experiences, and prevailing assumptions of designers, and, secondly, stimulated by the designer's interaction with the material in its context). In current designing practice, the approaches of identifying styling DNA can be done through algorithmic and manual.

## 3 CASE EXAMPLE ON ALGORITHMIC AND MANUAL APPROACHES

### 3.1 Algorithmic approach - Genetic Algorithm (Technology-driven)

The genetic algorithm is an evolutionary technique under the area of artificial intelligence. The use of computer is common to find and establish principle solution. Most of the existing research has given emphasis on developing brand image and identity of the car using genetic algorithm. The instrument used depends on computer technologies. For example, research on Changan Benben (Figure 1) tries to capture brand elements with integrated means through feature lines derived from designer experience [10]. They explore styling DNA by using an interactive generative design method to build up vehicle styling brand elements. From there, on the basis of the parameters, the chromosome of the lateral contour feature line can be represented mathematically.

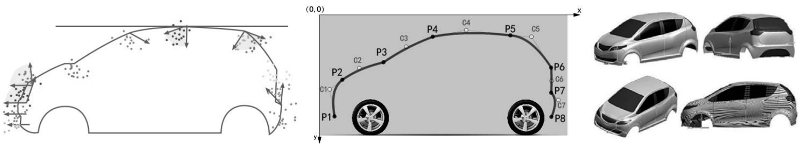



*Figure 1. Genetic Algorithm [10]*

Furthermore, in the understanding on vehicle styling and brand shape grammar through styling brand elements, they investigate rules to generate results on features lines and the brand identity. In their research, they claimed that the generations of styling brand feature lines were successfully applied in new Changan Benben design practice. Their experiment was based on Takagi's genetic algorithm theory [11], the interactive generative design of lateral contour feature lines consisted of four steps: coding initial population, setting up threshold, designing the operator, interactive generation and evaluation. However, there is no concrete evidence that genetic algorithms in genome construction can match with the aesthetical quality of the form attach with user perceive in design. This is differing with manual approach.

### 3.2 Manual approach - Human Visual Interaction (User-driven)

The manual approach is the way designer creating form reflects to natural resources as a source of inspiration. Many researches on manual approach regard affective elements in the studies. Several models of experience have been used to fit the human preferences into car design. According to Hiort af Ornäs [12], among all (1) Kansei Engineering, (2) Basic model of product emotions, (3) Framework of product experience, (4) The emotional design framework, (5) The four pleasures framework, and (6) Model of user experience.

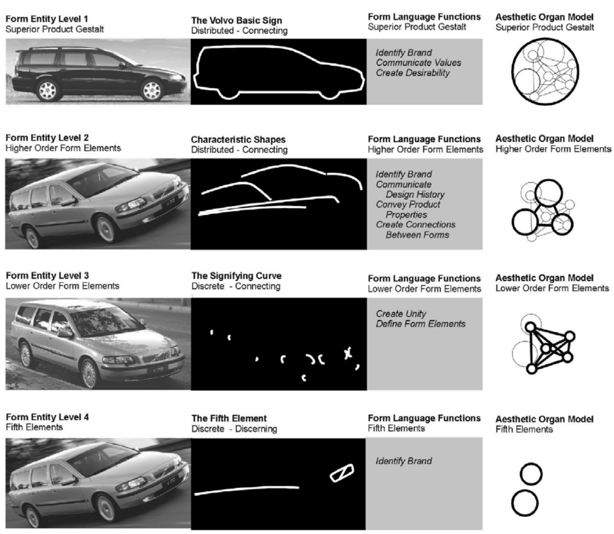



*Figure 2. Human Visual Interaction [9]*

Figure 2 provides an example of design syntactic (structure establishment) reasoning, including a coherent design format, and examples of form entities, aesthetic organs, and form elements for styling DNA of Volvo V70 Station Wagon. Warell [9] states there are four form entity levels in describing form entities, characteristics form elements, communicative functions and superimposed aesthetic organ models for Volvo V70. It can be identified through: 1) *The superior gestalt* consists of form entities and form elements of the highest hierarchical (global) level of the product form; 2) *Characteristic shapes:* Significant form elements are the pronounced shoulders running from the front of the car along its sides all the way to the taillights; 3) *A signifying curve* is found as a form ingredient in distributed across the car body: in the door handles, in the front lights, and in the grille, among other locations; and 4) *The fifth element:* The grille of the car featuring the distinctive diagonal cross member is a typical example of a 'fifth element,' a symbol for the Volvo brand of cars, which over the years has been seen in many different variations. It shows that the assessment of form focuses the element of consistency, selectively, and completeness [13]. The pattern of syntactic was embedded and the semantic (meaning carrying) language revealed based on the familiarities.

## 4 DISCUSSION

### 4.1 Challenges on Styling Strategies: Structured versus Emergent approaches

In this paper, we can see the strategies of form embodiment using algorithmic approach and manual approach are different. For algorithmic approach, it was structured. A form has been developed within the context of problem solving, normative, and synthesis-analysis. Meanwhile, for manual approach, it was emergent and seems more reflective and hermeneutics. The main challenges are that to match the aesthetical quality of form through an algorithm. Recently, research on Kansei Engineering (KE) tries to explore this kind of knowledge as a contribution to design methodology. KE focuses on product attributes and their relation to affective meaning [14]. KE explores the methodologies in measuring and tried to develop a model. KE systems have been applied in research and in the development of the car industries as a numerical tool to define affective response in relation to design features. However, the successful result derived from the study seems support Japan design market only. The methodologies are still fallacious and cannot be generalized to be used by other countries since it involve an issue of cultural (i.e., Ethnography and Demography) differences. The example was a Mazda Miata car which is successful in sales in Japan but not receive a similar feedback on sales in United States of America. After all, this effort was one of the attempts on identifying character traits of styling DNA for car design.

### 4.2 Styling DNA related to Car Design (Proton Prevé as an example)

In order to investigate styling DNA through the focal point/area of the car that contributes to brand image and identity of the organization, we have carried out a Design workshop among 30 designers at Proton. The purpose is to identify which elements designers' perceive most when looking at car design. Proton Prevé has been chosen as a case for this study. If we look at the popular choices among Proton designers', the item that represents local identity through nature resources by using Malayan tiger metaphor seems given a promising properties/attributes to the characteristics of styling DNA for car design (see Figure 3). The Malayan tiger (*Panthera tigris jacksoni*) is a tiger subspecies that inhabits the southern and central parts of the Malaysian Peninsula. Here, it shows how form elements positively correlated with shape character traits through syntactic and semantic properties of selected item. Furthermore, the item uses as a source of reference embodied agent makes styling DNA interpretations stand substantial from ambiguity. However, the connections between shape character traits, item and form language functions only can be seen at the three quarter front view through façade and side view of the car.

The study illustrates that this is the way of the normative and the reflective strategies thinking in design and designers' understanding of form character traits in relation to car styling DNA. The character traits of styling DNA are selective embedded at certain focal point/area and a portion of the car. The character embedded as a metaphorical form through line and curvature in motion as directional force, etc. Most Proton designers' believed that the uses of an algorithmic approach and manual approaches are equally important for car design. For them, it could generate an item from some encoded styling DNA known as a chromosome that mutated to class new items.

Other strategies of reasoning such as problem solving and synthesis-analysis using an algorithmic approach could provide variations of the findings. Hermeneutics is another way of establishing uniqueness of form on styling DNA since it involves an individual designer's interpretative and intuitive processes.

The next questions could be explored is on the perceived quality such as effective impacts on public perception, visual identity and corporate branding. This can give advantages to the research on styling DNA design methodology in both industry and education.

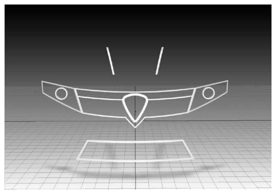
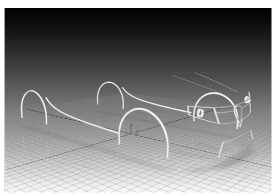
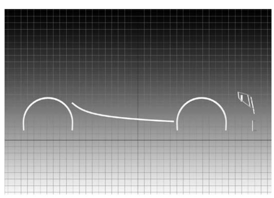
| Form elements | Shape character traits | Item – Nature resources (i.e., Malayan tiger metaphor) | Form language functions |
|---|---|---|---|
|  Front View |  |  | Convey product properties *i.e., (a) Tiger stare indicates aggression; (b) Nose symbolizes power; (c) Single graphic creates brand image; (d) Horizontal elements create wider perception; (e) Mouth expresses the sense of arousing desire.* |
|  Three Quarter Front View |  |  | Convey product properties *i.e., (a) Belly line shows the dynamic character; (b) Wheel arch trims shows the muscles;*<br>Create connections between forms *i.e., (c) Façade and side view** |
|  Side View |  |  | Convey product properties *i.e., (a) Belly line shows the dynamic character; (b) Muscles represents masculine.* |

*Figure 3. Form Elements in relation to Shape Character Traits, Item – Nature Resources, and Form Language Functions*

### 4.3 Advantages of Research on Styling DNA Design Methodologies in Education

Since styling DNA has become important in many car industries, the higher institution or design school should consider this as a part of special curriculum in the education. This can be done by setting up an appropriate parameter and weight age of design curriculum learning domain in education through the elements of mental skills (cognitive), growth in feelings or emotional areas (affective) and manual or physical skills (psychomotor) [15]. The curriculum should emphasize on giving understanding about styling DNA as a molecule that encodes the genetic instructions employed in the growth physical form or product. By doing that, students' reasoning ability on design thinking such as creative, critical and analytical could be increased. At the same time, the designs produced by students can be more promising and attach both user and technology requirements.

For industry, focuses on the styling DNA of the car are always with the reason for establishing the "State-of-the-Art" especially when it relates to the creation of brand image and identity of the company. Research on styling DNA both academic and industrial should address issues on genetic construction, contextual, and affective elements. Now, the challenges are how to create car character traits that can remain consistent in every production? Also, by establishing the fundamental fact about the uniqueness of the car, can it make the organizations or industries appear with their own originality?

## 5 CONCLUSION

This paper drew a major conclusion that styling DNA is important in determining the brand image and identity of the car and the organization. Even though, Algorithmic approach - Genetic Algorithm (Technology-driven) and Manual approach - Human Visual Interaction (User-driven) were the possible way to find the solutions, however, for both approaches, either in academia or industries, it seems that the expectation is more on identifying the character traits and relative attributes of styling DNA a molecule that encodes the genetic instructions employed in the growth and aesthetics appealing of form that can be used as a unified point of reference.

In future research, the combination of these two approaches that emphasize the complexity and addressing number of factors affecting a successful design outcome such as quality, cost, time, and capability might give better solutions in the creation of the brand image and identity building; and verifying could be extended to a larger setting, including facts or actual occurrences on practice. Such a setting could offer a structured approach to analyze value-based design cues of the organization through the model of styling DNA design methodologies for car design.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| Burgess, Jonathan | Aston University, United Kingdom | burgesjn@aston.ac.uk | 30 |
| Caro del Castillo Hernandez, Jorge Andres | Oslo and Akershus University College of Applied Sciences, Norway | jorgecarodelcastillo@gmail.com | 467 |
| Cartes, Jorge | Universidad del Bio-Bio, Chile | jcartes2000@gmail.com | 135 |
| Casha, Aaron | University of Malta, Malta | aaron.casha1@gmail.com | 650 |
| Chance, Shannon Massie | Hampton University, United States of America; Dublin Institute of Technology, Ireland | shannonchance@verizon.net, shannonchance7@gmail.com | 473 |
| Chen, Weiqin | Oslo & Akershus University College of Applied Sciences, Norway | Weiqin.Chen@hioa.no | 123, 147 |
| Childs, Peter | Imperial College London, United Kingdom | p.childs@imperial.ac.uk | 669 |
| Christis, Naomi | AnSyMo, Department of Mathematics and Computer Science, Faculty of Science, Universtiy of Antwerp | Naomi.Christis@uantwerpen.be | 111 |
| Coninx, Karin | Universiteit Hasselt-tUL-iMinds, EDM, Belgium | karin.coninx@uhasselt.be | 166 |
| Connor, Christopher John | Northumbria University, United Kingdom | chris.connor@northumbria.ac.uk | 249 |
| Corremans, Jan | University of Antwerp, Belgium | jan.corremans@uantwerpen.be | 294 |
| Covill, Derek | University of Brighton, United Kingdom | d.covill@brighton.ac.uk | 255 |
| Crea, Nicola | Politecnico di Milano, Italy | nicola.crea@polimi.it | 366 |
| Daams, Brecht J. | Daams Ergonomie, The Netherlands | daams@ergonomie.nl | 461 |
| Danckaers, Femke | Vision Lab, Faculty of Science, University of Antwerp, Iminds, Belgium | femke.danckaers@uantwerpen.be | 111 |
| Das, Amarendra Kumar | Indian Institute of Technology Guwahati, India | dasak@iitg.ernet.in | 117 |
| de Boer, Johannes | Research Center for Design and Technology, Saxion University of Applied Sciences, Enschede, The Netherlands; Human Media Interaction, University of Twente, Enschede, The Netherlands | j.deboer@saxion.nl | 420 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| De Bruyne, Guido | Product Development, Faculty of Design Science, University of Antwerp, Belgium | guido.debruyne@uantwerpen.be | 111 |
| de Eyto, Adam | Product Design & Technology, University of Limerick, Ireland | Adam.DeEyto@ul.ie | 437 |
| de Lange, Clemens | Delft University of Technology, Social Cohesion Design Foundation, The Netherlands | C.J.M.deLange@tudelft.nl | 384 |
| De Roeck, Dries | Antwerp of University, Belgium | dries.deroeck@uantwerpen.be | 54 |
| de Vere, Ian | Brunel University, London, United Kingdom | Ian.deVere@brunel.ac.uk | 530 |
| Deiters, Arne | Leibniz University of Hannover, Germany | deiters@ipeg.uni-hannover.de | 213 |
| Dertien, Edwin | University of Twente, The Netherlands | e.dertien@utwente.nl | 562 |
| Dewit, Ivo | Antwerp of University, Belgium | ivo.dewit@uantwerpen.be | 54 |
| Dias, Ana Cristina | Faculty of Architecture – University of Lisbon \| CIAUD, Portugal | a.cristinadias@hotmail.com | 726 |
| Didaskalou, Alexandros | Designlab (edg designlab EPE), Greece | alexandros@designlab.gr | 166 |
| Diels, Cyriel | Coventry University, United Kingdom | cyriel.diels@coventry.ac.uk | 203 |
| Duncan, Trevor | Northumbria University, United Kingdom | trevor.duncan@northumbria.ac.uk | 443 |
| Eggink, Wouter | University of Twente, The Netherlands | w.eggink@utwente.nl | 87, 226, 568 |
| Ehlhardt, Huub | University of Twente, The Netherlands | huub.ehlhardt@gmail.com | 320 |
| Elton, Eddy | University of Brighton, United Kingdom | e.elton@brighton.ac.uk | 255 |
| Endedijk, Maaike | ATLAS University College, University of Twente, Enschede, The Netherlands | m.d.endedijk@utwente.nl | 377 |
| Eriksen, Kaare | Aalborg University, Denmark | eriksen@create.aau.dk | 219 |
| Facin, Ana Lúcia Figueiredo | University of São Paulo, Brazil | afacin@usp.br | 624 |
| Farrugia, Philip | University of Malta, Malta | philip.farrugia@um.edu.mt | 650 |
| Fontana, Isabela Mantovani | Universidade de São Paulo, Brazil | isabelafontana@gmail.com | 498, 624 |
| Forkes, Andrew | London South Bank University, United Kingdom | forkesa@lsbu.ac.uk | 390, 426 |
| Fosse, Jarle | Oslo and Akershus University College of Applied Science, Norway | jarleboy@hotmail.com | 282 |
| Fox, Stephan | ETH Zurich, Switzerland | sfox@ethz.ch | 36 |
| Frost, Katherine | City University London, United Kingdom | frost.katherine@gmail.com | 346, 492 |
| Furner, Tressa Ellen | Brigham Young University, United States of America | tressaellen@gmail.com | 209 |
| Garde, Julia | University of Twente, The Netherlands | j.a.garde@utwente.nl | 14 |
| Garland, Nigel | Sustainable Design Research Centre, Bournemouth University, United Kingdom | ngarland@bournemouth.ac.uk | 612 |
| Geraedts, Jo | TU Delft, The Netherlands | J.M.P.Geraedts@tudelft.nl | 720 |
| Gerhard, Detlef | Vienna University of Technology, Austria | detlef.gerhard@tuwien.ac.at | 543 |
| Ghassan, Aysar | Coventry University, United Kingdom | aysar.ghassan@coventry.ac.uk | 203 |
| Gidion, Gerd | Karlsruhe Institute of Technology (KIT), Germany | gerd.gidion@kit.edu | 644 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| Giese, Holger | Hasso-Plattner-Institut für Softwaresystemtechnik GmbH, Germany | holger.giese@hpi.uni-potsdam.de | 68 |
| Gill, Carolina | The Ohio State University, United States of America | gill.175@osu.edu | 302 |
| Gonzalez Almaguer, Carlos Alberto | Monterrey Institute of Technology and Higher Education Campus Queretaro, Mexico | cgonzalz@itesm.mx | 700 |
| Gonzalez Gonzalez, Grecia | Monterrey Institute of Technology and Higher Education Campus Queretaro, Mexico | greciaglz92@gmail.com | 700 |
| Grande, Julie | NTNU, Norway | jugr008@gmail.com | 432 |
| Gulden, Tore | Oslo og Akershus University College of Applied Sciences, Norway | tore.gulden@hioa.no | 60 |
| Gundersen, Gunnar | Oslo and Akershus University College of Applied Sciences, Norway | gunnarh.gundersen@hioa.no | 676 |
| Gwashavanhu, Elton | City University, London, United Kingdom | Elton.Gwashavanhu.1@city.ac.uk | 492 |
| Hadfield, Mark | School of Design, Engineering & Computing, Bournemouth University, England | MHadfield@bournemouth.ac.uk | 437 |
| Håkansson, Anders | Luleå University of Technology, Sweden | anders.hakansson@ltu.se | 414 |
| Halonen, Nillo | Tampere University of Technology, Finland | nillo.halonen@tut.fi | 682 |
| Handschuh, Sebastian | VPE Network e.V, Germany | s_handschuh@gmx.de | 334 |
| Hasling, Karen Marie | Kolding School of Design, Denmark | kmh@dskd.dk | 396 |
| Hassan, Halim | Perusahaan Otomobil Nasional Sdn Bhd (PROTON), Malaysia | HALIMH@proton.com | 738 |
| Hasselknippe, Kathinka | NTNU, Norway | kathinka.hasselknippe@gmail.com | 308 |
| Helmich, Annica | Karlsruhe Institute of Technology (KIT), Germany | annica.helmich@kit.edu | 644 |
| Hiort af Ornäs, Viktor | Chalmers University of Technology, Sweden | hiort@chalmers.se | 42, 600 |
| Holmqvist, Bengt | Luleå University of Technology, Sweden | beho@ltu.se | 372 |
| Homminga, Jasper | ATLAS University College, University of Twente, Enschede, The Netherlands | j.j.homminga@utwente.nl | 377 |
| Hortop, Amy | TU Braunschweig, Germany | a-b.hortop@tu-braunschweig.de | 213 |
| Howell, Bryan | Brigham Young University, United States of America | bryan.howell@byu.edu | 153 |
| Huerta, Ricardo | Monterrey Institute of Technology and Higher Education Campus Queretaro, Mexico | A01201372@itesm.mx | 700 |
| Humphries-Smith, Tania Maxine | Bournemouth University, United Kingdom | thumphri@bournemouth.ac.uk | 485 |
| Hutchings, Maggie | School of Health and Social Care, Bournemouth University, United Kingdom | mhutchings@bournemouth.ac.uk | 437 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| Huysmans, Toon | Vision Lab, Faculty of Science, University of Antwerp, Iminds,Belgium | toon.huysmans@uantwerpen.be | 111 |
| Isa, Siti Salwa | NUST, Norway | salwaisa@yahoo.com | 580 |
| Jauregui Becker, Juan | University of Twente. Lab of Design, Production and Management. The Netherlands | j.m.jaureguibecker@ctw.utwente.nl | 688 |
| Juuti, Tero Sakari | Tampere University of Technology, Finland | tero.juuti@tut.fi | 682 |
| Kakati, Vikramjit | Indian Institute of Technology Guwahati, India | vikramjit@iitg.ac.in | 117 |
| Kantorovitch, Julia | Teknologian Tutkimuskeskus VTT, Finland | Julia.Kantorovitch@vtt.fi | 166 |
| Katz, Tim | University of Brighton, United Kingdom | t.katz@bton.ac.uk | 255 |
| Keitsch, Martina | NUST, Norway | martina.keitsch@ntnu.no | 600, 606 |
| Keller, Ianus | TU Delft, The Netherlands | ianus@forinspirationonly.com | 720 |
| Khan, Zulfiqar | Sustainable Design Research Centre, Bournemouth University, United Kingdom | zkhan@bournemouth.ac.uk | 612 |
| Kolb, Steffen | HTW Berlin University of Applied Science, Germany | steffen.kolb@htw-berlin.de | 402 |
| Koohgilani, Mehran | Bournemouth University, United Kingdom | mkoohgil@bournemouth.ac.uk | 184 |
| Kovacevic, Ahmed | City University London, United Kingdom | a.kovacevic@city.ac.uk | 346 |
| Krab-Hüsken, Leonie E. | ATLAS University College, University of Twente, Enschede, The Netherlands | leonie.krab@utwente.nl | 377 |
| Kujansuu, Päivi | University of Tampere, Finland | kujansuu.paivi.m@student.uta.fi | 682 |
| Kurikka, Joona | Aalto University, Finland; CERN, Switzerland | j@wr.fi | 504 |
| Kurtcuoglu, Vartan | ETH Zurich, Switzerland | kvartan@ltnt.iet.mavt.ethz.ch | 36 |
| Lachmayer, Roland | Leibniz University of Hannover, Germany | lachmayer@ipeg.uni-hannover.de | 213 |
| Lacko, Daniel | Product Development, Faculty of Design Science, University of Antwerp, Belgium; Vision Lab, Faculty of Science, University of Antwerp, Iminds | daniel.lacko@uantwerpen.be | 111 |
| Lai, Yoke-Chin | VIA University College, Denmark | lyc@via.dk, lyc@viauc.dk | 479 |
| Laing, Richard | IDEAS Research Institute, The Robert Gordon University, Scotland | r.laing@rgu.ac.uk | 166 |
| Langenbach, Joachim | Technical University of Clausthal, Germany | joachim.langenbach@tu-clausthal.de | 213 |
| Langeveld, Lau | Delft University of Technology, The Netherlands | l.h.langeveld@tudelft.nl | 288 |
| Langlotz, Martin | VPE Network e.V., Germany | martin.langlotz@em.ag | 334 |
| Ledsome, Colin | IED, United Kingdom | colin.ledsome@btinternet.com | 244 |
| Lehtonen, Timo | Tampere University of Technology, Finland | timo.lehtonen@tut.fi | 682 |
| Leininger, Troy Austin | Brigham Young University, United States of America | troyleininger@gmail.com | 263 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| Lenau, Torben | Technical University of Denmark, Denmark | lenau@mek.dtu.dk | 396 |
| Leong, Benny | Hong Kong Polytechnic University, Hong Kong | benny.leong@polyu.edu.hk | 510 |
| Leurs, Bas | Rotterdam University of Applied Sciences, The Netherlands | basleurs@gmail.com | 178 |
| Leutenecker, Bastian | ETH Zurich, Switzerland | bleutenecker@ethz.ch | 190 |
| Liapis, Aggelos | INTRASOFT International SA, Greece | Aggelos.LIAPIS@intrasoft-intl.com | 166 |
| Liem, Andre | NUST, Norway | andre.liem@ntnu.no | 580 |
| Linda, Sara | City University London, United Kingdom | sara.linda.1@city.ac.uk | 346, 492 |
| Lindemann, Udo | Technische Universität München, Germany | lindemann@pe.mw.tum.de | 354 |
| Lindley, Julian | University of Hertfordshire, United Kingdom | j.lindley@herts.ac.uk | 172, 555 |
| Little, Derek | University of Strathclyde, United Kingdom | derek.little@strath.ac.uk | 408 |
| Lloveras, Joaquim | Technical University of Catalonia (UPC), Spain | j.lloveras@upc.edu | 197, 700 |
| Lohmeyer, Quentin | ETH Zurich, Switzerland | qlohmeyer@ethz.ch | 99 |
| Lohrengel, Armin | Technical University of Clausthal, Germany | lohrengel@imw.tu-clausthal.de | 213 |
| Loy, Jennifer | Griffith University, Australia | j.loy@griffith.edu.au | 74, 276 |
| Lundh, Maud Veronica Gine | Oslo and Akershus University College of Applied Sciences, Norway | maud.gine.lundh@gmail.com | 123 |
| Maciver, Fiona | IDEAS Research Institute, The Robert Gordon University, Scotland | f.maciver1@rgu.ac.uk | 166 |
| Mader, Angelika | University of Twente, The Netherlands | a.h.mader@utwente.nl | 562, 568 |
| Maher, Carmel | designcore, Institute of Technology, Carlow, Ireland | carmel.maher@itcarlow.ie | 437 |
| Malins, Julian Paul | IDEAS Research Institute, The Robert Gordon University, Scotland | j.malins@rgu.ac.uk | 166 |
| Manriquez, Jose | Monterrey Institute of Technology and Higher Education Campus Queretaro, Mexico | jmanriqu@itesm.mx | 700 |
| Markopoulous, Panos | Technische Universiteit Eindhoven, The Netherlands | P.Markopoulos@tue.nl | 166 |
| Marsh, Phillipa | NTU, United Kingdom | phillipa.marsh@ntu.ac.uk | 26 |
| Masen, Marc | Imperial College London, United Kingdom | m.masen@imperial.ac.uk | 669 |
| McGonigal, Stephen | University of Hertfordshire, United Kingdom | s.g.mcgonigal@herts.ac.uk | 172, 555 |
| McLaren, Andrew | University of Strathclyde, United Kingdom | andrew.mclaren@strath.ac.uk | 408 |
| McLening, Christian | Aston University, United Kingdom | c.mclening@aston.ac.uk | 30 |
| Meboldt, Mirko | ETH Zurich, Switzerland | meboldtm@ethz.ch | 36, 99, 190, 618 |
| Menning, Axel | Hasso-Plattner-Institut für Softwaresystemtechnik GmbH, Germany | axel.menning@hpi.uni-potsdam.de | 68 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| Michailidou, Ioanna | Technische Universität München, Germany | michailidou@pe.mw.tum.de | 354 |
| Milne, Mark | University of Brighton, United Kingdom | m.milne@brighton.ac.uk | 255 |
| Moen, Bente | Oslo and Akershus University College of Applied Science, Norway | bente.moen@gmail.com | 282 |
| Mora, Marcela | Universidad del Bio-Bio, Chile | mamora@ubiobio.cl | 135 |
| Moreira da Silva, Fernando | Faculty of Architecture – University of Lisbon \| CIAUD, Portugal | fms.fautl@gmail.com | 726 |
| Moreland, Jessica | The Ohio State University, United States of America | jessicamoreland@me.com | 302 |
| Morgan, David | Brigham Young University, United States of America | dcmorgan@byu.edu | 209, 456 |
| Morris, Richard | University of Brighton, United Kingdom | r.d.morris@brighton.ac.uk | 255 |
| Mulder-Nijkamp, Maaike | University of Twente, The Netherlands | m.mulder-nijkamp@utwente.nl | 294 |
| Mussgnug, Moritz | ETH Zurich, Switzerland | mmussgnug@ethz.ch | 99, 190 |
| Nicolai, Claudia | Hasso-Plattner-Institut für Softwaresystemtechnik GmbH, Germany | Claudia.Nicolai@hpi.uni-potsdam.de | 68 |
| Nielsen, Brita Fladvad | NTNU, Norway | brita.nielsen@ntnu.no | 308, 432 |
| Nikitas, Alexandros | Chalmers University of Technology, Sweden | alexandros.nikitas@chalmers.se | 159 |
| Noli, Dominik | ETH Zurich, Switzerland | nolid@ethz.ch | 190 |
| Öhrling, John Daniel | Luleå University of Technology, Sweden | johdan@ltu.se | 372 |
| Ordoñez, Isabel | Chalmers University of Technology, Department of Product and Production Development, Sweden | isabel.ordonez@chalmers.se | 360 |
| O'Rourke, Pearl | Dublin Institute of Technology, Ireland | pearl.orourke@dit.ie | 473 |
| Osmond, Jane | Coventry University, United Kingdom | j.osmond@coventry.ac.uk | 8 |
| Oswald, David | HTW Berlin University of Applied Science, Germany | david.oswald@htw-berlin.de | 402 |
| Othman, Azlan | Perusahaan Otomobil Nasional Sdn Bhd (PROTON), Malaysia | azlant@proton.com | 738 |
| Ovesen, Nis | Department of Architecture, Design and Media Technology, Aalborg University, Denmark | nove@create.aau.dk | 2, 219, 714 |
| Patiño Santa, Luis Fernando | EAFIT University, Colombia | lpatino@eafit.edu.co | 328 |
| Pavel, Nenad | Oslo and Akershus University College of Applied Science, Norway | nenad.pavel@hioa.no | 314, 694 |
| Pérez, Marcela | Universidad del Bio-Bio, Chile | psmarcelaperez@gmail.com | 135 |
| Petrova, Miroslava | University of Forestry, Bulgaria | mirap13@yahoo.com | 524 |
| Polo, Viviana | Universidad de San Buenaventura, Colombia | v.polo.educacion@gmail.com | 130 |
| Powell, John | Bournemouth University, United Kingdom | JPowell@bournemouth.ac.uk | 485 |
| Preca, George | University of Malta, Malta | georgepreca@gmail.com | 650 |
| Presoto, Anderson Edilson | Universidade de São Paulo, Brazil | anderson.presoto@gmail.com | 498, 624 |
| Rahe, Ulrike | Chalmers University of Technology, Sweden | ulrike.rahe@chalmers.se | 42, 159, 360 |
| Rane, Sham | City University London, United Kingdom | sham.rane.1@city.ac.uk | 346, 492 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| Rättyä, Kaisu | University of Eastern Finland, Finland | kaisu.rattya@uef.fi | 682 |
| Read, Matthew | City University London, United Kingdom | Matthew.Read.3@city.ac.uk | 492 |
| Reikvam, Gudrun | NTNU, Norway | reikvam.gudrun@gmail.com | 308 |
| Reitan, Janne | Oslo and Akershus University College of Applied Sciences, Norway | janne.reitan@hioa.no | 632 |
| Rexfelt, Oskar | Chalmers University of Technology, Sweden | rex@chalmers.se | 42, 360 |
| Roth, Michael | Technische Universität München, Germany | roth@pe.mw.tum.de | 354 |
| Samatar, Mohamoud | City University London, United Kingdom | Mohamoud.samatar.1@city.ac.uk | 492 |
| Samsudin, Zaidy | Perusahaan Otomobil Nasional Sdn Bhd (PROTON), Malaysia | ZAIDYS@proton.com | 738 |
| Sanders, Emma | The Ohio State University, United States of America | errrmma@gmail.com | 302 |
| Sauer, Thorsten | DHBW Baden-Wuerttemberg Cooperative State University Ravensburg, Germany | sauer@dhbw-ravensburg.de | 574 |
| Sayer, Phillip | University of Strathclyde, United Kingdom | p.g.sayer@strath.ac.uk | 408 |
| Schulte, Kjersti | NUST, Norway | kjersti.schulte@ntnu.no | 600 |
| Scully, Amos | Rochester Institute of Technology, United States of America | amos.scully@rit.edu | 592 |
| Setola, Bruno | Rotterdam University of Applied Sciences, The Netherlands | brunosetola@gmail.com | 178 |
| Shafiq, Sultan | City University London, United Kingdom | Sultan.Shafiq.1@city.ac.uk | 492 |
| Shamsuddin, Zafruddin | Perusahaan Otomobil Nasional Sdn Bhd (PROTON), Malaysia | zafruds@proton.com | 738 |
| Sharif, Mohammed | City University London, United Kingdom | Mohammed.Omar.1@city.ac.uk | 492 |
| Siggard, Jennifer Liane | Brigham Young University, United States of America | siggardj@gmail.com | 209 |
| Sijbers, Jan | Vision Lab, Faculty of Science, University of Antwerp, Iminds | jan.sijbers@uantwerpen.be | 111 |
| Sjovøll, Vibeke | Oslo and Akershus University College of Applied Science, Norway | vibeke.sjovoll@hioa.no | 105, 549 |
| Skjelbred, Bente | Oslo og Akershus University College of Applied Sciences, Norway | bente.skjelbred@hioa.no | 60 |
| Skulberg, Harald | The Oslo School of Architecture and Design, Norway | harald.skulberg@aho.no | 732 |
| Soares, Susana | London South Bank University, United Kingdom | soaress@lsbu.ac.uk | 426 |
| Sonneveld, Marina Henrieke | Delft Universtity of Technology, The Netherlands | m.h.sonneveld@tudelft.nl | 450 |
| Souza, Roberta | Universidade de São Paulo, Brazil | csouzaroberta@gmail.com | 498, 624 |
| Spence, Peter | Imperial College London, United Kingdom | peter.spence@network.rca.ac.uk | 669 |
| Spencer, Nicholas | Northumbria University, United Kingdom | nick.spencer@unn.ac.uk | 510 |

| Name | Organisation | Email | Page No. |
|---|---|---|---|
| Stam, Liesbeth | University of Twente, The Netherlands | l.m.stam@student.utwente.nl | 226 |
| Steen-Hansen, Linn | Oslo and Akershus University College of Applied Sciences, Norway | linndroid83@gmail.com | 123 |
| Stilma, Margot | Saxion University of Applied Sciences, The Netherlands | m.d.c.stilma@saxion.nl | 420, 516 |
| Stokholm, Marianne | Aalborg University, Denmark | ms@create.aau.dk | 268 |
| Stoltenberg, Einar | Oslo and Akershus University College of Applied Science, Norway | einar.stoltenberg@hioa.no | 105, 632 |
| Stücheli, Marius | ETH Zurich, Switzerland | mstuecheli@ethz.ch | 618 |
| Sumsion, Cecily | Brigham Young University, United States of America | cecilysumsion@gmail.com | 209 |
| Teeuw, Wouter | Research Center for Design and Technology, Saxion University of Applied Sciences, Enschede, The Netherlands | w.b.teeuw@saxion.nl | 420 |
| Teklemariam, Hailu Gebretsadik | Indian Institute of Technology Guwahati, India | hailug@gmail.com | 117 |
| Thalen, Jos | University of Twente, The Netherlands | j.p.thalen@utwente.nl | 14 |
| Thomsen, Bente Dahl | Department of Architecture, Design and Media Technology, Aalborg University, Denmark | bdt@create.aau.dk | 2, 48 |
| Thomson, Avril Isabel | University of Strathclyde, United Kingdom | avril.thomson@strath.ac.uk | 408 |
| Thoring, Katja | Hochschule Anhalt Dessau, Germany | k.thoring@design.hs-anhalt.de | 20 |
| Tollestrup, Christian | Aalborg University, Denmark | cht@create.aau.dk | 340 |
| Törlind, Peter | Luleå University of Technology, Sweden | peter.torlind@ltu.se | 414 |
| Tovey, Michael John | Coventry University, United Kingdom | m.tovey@coventry.ac.uk | 8 |
| Townsend, Barney | London South Bank University, United Kingdom | townseba@lsbu.ac.uk | 390 |
| Trathen, Stephen | University of Canberra, Australia | Stephen.Trathen@canberra.edu.au | 706 |
| Tsvetanova, Yordanka | Forest University Sofia, Bulgaria | dani_zv@abv.bg | 93 |
| Ugurlu, Sinan | Vienna University of Technology, Austria | sinan.ugurlu@tuwien.ac.at | 543 |
| Underwood, Gary | Bournemouth University, United Kingdom | gunderwood@bournemouth.ac.uk | 537 |
| Utriainen, Tuuli Maria | Aalto University, Finland; CERN, Switzerland | tuuli.maria.utriainen@cern.ch | 504 |
| van Beurden, Karin | Saxion KCDT, The Netherlands | k.m.m.vanbeurden@saxion.nl | 420, 516, 657 |
| van Boeijen, Annemiek | Delft University of Technology, The Netherlands | a.g.c.vanboeijen@tudelft.nl | 232 |
| Van den Berg, Frank | ATLAS University College, University of Twente, Enschede, The Netherlands | f.m.j.w.vandenberg@utwente.nl | 377 |
| van der Voort, Mascha | University of Twente, The Netherlands | m.c.vandervoort@utwente.nl | 14 |
| van Os, Gerard | Saxion, The Netherlands | g.c.m.vanos@saxion.nl | 657 |
| Vanhatalo, Mikko | Tampere University of Technology, Finland | mikko.vanhatalo@tut.fi | 682 |
| Varekamp, Tommie | TU Delft, The Netherlands | tommievarekamp@gmail.com | 720 |


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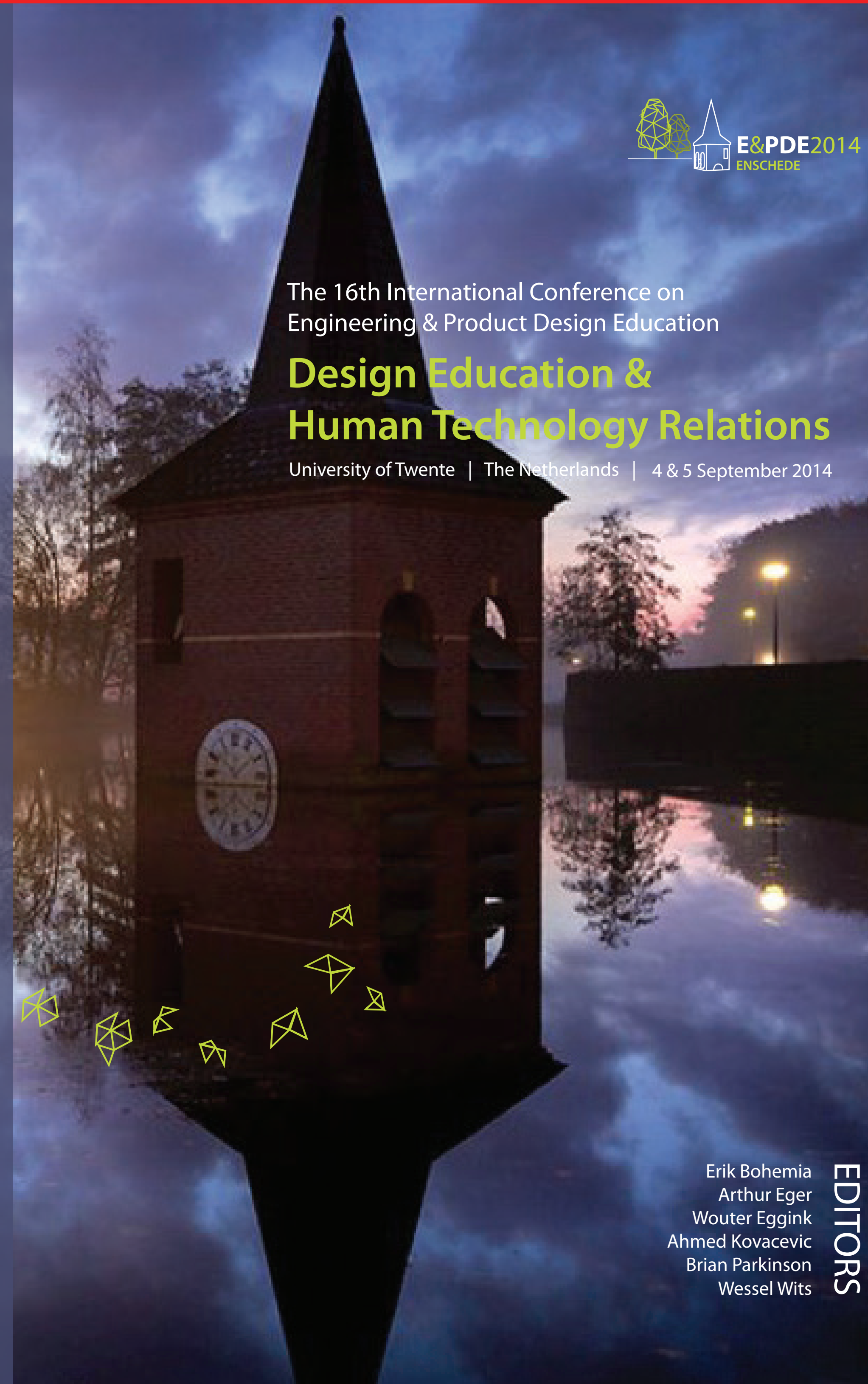

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# Design Education & Human Technology Relations

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EDITORS
Erik Bohemia
Arthur Eger
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