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DESIGN SCHOOL

E&PDE 2015

The 17th International Conference on Engineering & Product Design Education

Great Expectations: Design Teaching, Research & Enterprise

3rd - 4th September 2015

EDITORS

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Brian Parkinson and Darren Southee

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Great Expectations: Design Teaching, Research & Enterprise

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Foreword

Great Expectations: Design Teaching, Research & Enterprise

The 17th International Conference on Engineering and Product Design Education (E&PDE) was held at Loughborough Design School (LDS), Loughborough University, UK on the 3rd and 4th of September 2015.

The conference was hosted by LDS 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 series began in 1979 in the UK. In that year I was a member of the first cohort of students in our school to study GCE 'O' level Computer Science. We were taught by our mathematics teacher (who reportedly was a week or two ahead of us in the syllabus) and we used five hole punched paper tape to input to our computer. The home computer was yet to arrive on the scene, with the Sinclair ZX80 under development at The Mill in St. Ives, Cambs (released in 1980 at £99.95, UK).

Product Design, in 2015, has many fundamental differences to Product Design in 1979 and, while much of the heart of engineering theory existed at that time, Engineering Design (and practice) in 2015 has also undergone multiple transformations over the thirty six year period.

On Wednesday 8th July 2015, I attended an event at St James's Palace, London where the Duke of Edinburgh, a patron of the Institute for Engineering Designers (IED), hosted a celebration of the 70 year anniversary of the IED, he also conferred the newly established status of Chartered Technological Product Designer (CTPD) upon the first five candidates to meet the requirements.

Chartered Engineer status (UK), on the other hand, followed the establishment of the Engineering Council, gaining a Royal Charter on 27 November 1981 and offering verified recognition of professional competencies through training and monitored professional practice experience. Applications for registrations have reportedly increased in recent years suggesting that industry acknowledges and rewards those who have achieved this status.

Engineering and Product Design then have essentially been through evolution and revolution in the intervening years since the E&PDE conference series began.

The programme committee agreed, "Great Expectations: Design Teaching, Research & Enterprise", as the headline theme, captured some prevailing perceptions associated with Higher Education Institutes (HEIs) involved in Engineering and Product Design Education. HEIs, it appears, are required to output humans able to meet industry, government and societal demands for productivity, innovation, happiness and lifelong adaptability.

Our keynote speaker, Sebastian Conran, brings wisdom gained in Industry at Sebastian Conran Associates, to present "The Importance of Design" arguing that there is a clear business-case for the use of rigorous Design Process and Creative Thinking tools in early stage innovation. Such an approach, he suggests, can be even more effective for industry.

Professor Dale Russell, also a keynote speaker, reflects upon her experiences in Design Education at The Royal College of Art and Central Saint Martins UAL to present, "One Step Beyond: An Open Culture of Transcending Boundaries Towards Innovation", looking back at the open culture of discourse and experimentation in the late 1980s, through to a transdisciplinary fusion of research investigation and experimentation in pedagogical and commercial design innovation to initiate insight and understandings for people-centred design as we shape our future.

Globalisation, the process of international integration arising from interchanges of world views, products and ideas, previously focused on the economic perspective only, also projects a very different picture in 2015 to that in 1979. It is pleasing to see representatives from more than 30 countries at this year's E&PDE conference. This allowed the committee to construct a programme with major streams including:

- Promoting Creativity and Innovation in Design & Engineering
- Ethics and Social Issues
- Benefits of Collaboration in Design & Engineering
- International Collaboration
- Project/Problem Based Learning
- Bachelors, Masters and PhDs in Design & Engineering
- Design & Engineering Metrics & Assessment
- Informing Design & Engineering Pedagogy with Research & Enterprise
- Technology Integration, Application & Knowledge Transfer
- Design & Engineering Pedagogical Practice

The quality papers submitted and accepted under these streams offer an opportunity to frame, provoke and progress toward an Engineering and Product Design Education culture fit for purpose at the present time and into the future.

This 2015 edition of the E&PDE conference was made possible through the commitment and efforts of many people. Special thanks go to Judith Grace, Ahmed Kovacevic, Brian Parkinson, Erik Bohemia and Andrew Weeks for their excellent wisdom in organizing this conference. Nadine Pearce and Charlotte Whitehead from the Institution of Engineering Designers who have carried out sterling work throughout.

We would sincerely like to thank all the members of the international academic review board.

On behalf of the conference programme committee:

Dr. Darren Southee
Programme Director Product Design & Technology (BSc)
Loughborough Design School
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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, Seoul and 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.

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Established in 1945, Incorporated by Royal Charter in 2012, the Institution of Engineering Designers is the premier 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 service. 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).

2015 has seen the launch of a new Chartership for Product Designers. CTPD (Chartered Technological Product Designer) is on-a-par with all other Chartered registrations and exists to provide professional recognition and standing to those suitably qualified and competent persons working in Product Design.

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, and find out more about becoming a member of the IED at http://www.ied.org.uk

The Importance of Design

Sebastian Conran, Sebastian Conran Associates

Summary of Keynote

There is a clear business-case for using rigorous Design Process and Creative Thinking tools in early stage innovation can be even more effective for industry for multiple reasons: more innovative & appealing products, simpler manufacturing, quicker responsiveness, and shorter product-development timescales. All of which leads to greater product resilience, customer satisfaction, less aftersales resource and ultimately better profitability.

Although its meaning has become quite nebulous the word Design derives from Latin designare; scheme, plan, mark out, devise, choose, designate, appoint. The designer is literally "one who schemes" and creates the vision for others to follow.

Traditionally Britain has a culture that believes in amateurism and that anyone 'creative' could design something nice. There is often a tendency to view design as a sort of marketing tool used in the selling process to package and communicate the product offer. However in a contemporary world - whether Porsche, Dyson or Apple - if aiming to offer globally outstanding product then excellent thoughtful design is essential to achieve success.

Professional design exists within a wide bandwidth of disciplines including: industrial, architecture, interface, product-styling, graphic and fashion. Designers tend to specialize in specific fields such as: automotive, built environment, luxury, strategic, branding, or web design. For example industrial designers are trained and experienced in product innovation and industrial fabrication. They are skilled at collaborating successfully within technical teams throughout the product development process; they tend to think rigorously and in the long term. However with buying seasons twice a year the more intuitive fashion designer is obliged to follow an entirely different schedule.

The choice of which discipline is appropriate for a specific task, and when & where in the innovation process is best applied significantly impact on the outcome of a project. What is the scale and impact of the challenge – do you need a nurse or a neurosurgeon, or perhaps a more of a generalized practitioner? Whatever the choice of designer, both talent and experience can count for a lot and some are better than others.

The one thing that all designers should have in common is that they employ their creativity and experience to create the maximum Value (as in perception of fair exchange), whilst using available resources as efficiently as possible.

Another way of looking at it is that value consists of brand, design and quality, divided by cost.

Key Message:

Outstanding design can leverage excellence and success from your business; do not leave it too late, design is not just the marketing graphics & logos, wrappers & websites, posters & packaging – although it is part of it, this comes towards the end of the process. Design needs to be the first thought as well as the last.

One Step Beyond: An Open Culture of Transcending Boundaries Towards Innovation

Professor Dale Russell, Royal College of Art
& Central Saint Martins UAL & Russell Studio

Summary of Keynote

In the late 80s an open culture of discourse and experimentation took place by default. Today this same open culture is required that inspires the willingness to transcend boundaries while acknowledging excellence of innovation and rigor demanded within the fusion of engineering, scientific and design innovation.

Left-field visioning in a corporate culture is reliant on knowledge flow within an innovation ecosystem without boundaries. Forming a synthesis addressing society, user-centricity and technology that rely upon delicate dialogue between scholastic research and commercial innovation practice.

Transition in change through strategic frameworks for disruptive iteration provoke impact of meaningful exchange created by practitioner and educator as protagonist in the provision of peripatetic practice on an international platform between academia and corporations. As we progressed through landline to cloud, numerous questions and observations are provoked and include: Social responsibility? Need for permanency? What is the role of artefact? Material metamorphosis? Positioning of the hacker?

As advocate for the integration of the intuitive and the pragmatic within tangible and intangible product development, this has led to progressing a transdisciplinary fusion of research investigation and experimentation in pedagogical and commercial design innovation through the synthesis of foresight, research and practice to initiate insight and understandings for people-centred design as we shape our future.

Chapter 1

Exploring Design Education

SCIENCE INFORMED DESIGN: INVOLVING THE PHYSICAL AND NATURAL SCIENCES

John R McCARDLE
Loughborough Design School, Loughborough University UK

ABSTRACT
Eminent designers and engineers have historically been cited as inspirational polymaths with the ability to utilize a wide range of information to form a rational idea and create a concept. If educators are ever to encourage students of Design to emulate such skills then nurturing the growth of philomathic attitudes is essential. Part of that process is developing the ability to draw together observations from a far broader range of disciplines than those currently and commonly drawn upon in most design curricula, and integrating these into common practice.
Biomimetics offers many opportunities in design to broaden scientific inquiry. Such approaches currently lack formality as a design methodology and are consequently relatively scarce in application, but successful outcomes tend to capture student imagination. As such, biomimetics can provide an inspirational and highly educational direction for students to take and therefore has the scope to be a powerful learning mechanism.
This paper illustrates directions taken by design students of Product Design and Technology (BSc) and Industrial Design and Technology (BA). The interdisciplinary methods of studying, replicating and harnessing natural phenomena for design education and design practice demonstrates the potential as an avenue for learning that students considered inaccessible or even irrelevant. Above all it adds to the debate of designer skill sets and the need to bridge the current gulf between design practice and science.

Keywords: Design, science, biomimetic, education.

1 INTRODUCTION
The concept of multi-disciplinary design and inter-disciplinary working has been a well-established part of industrial design curricula at universities since the late 1960s. Since then the design of tangible products has seen a renaissance in methodologies driven by competitive business, market driven economies and the discerning user. More recently the inception of 'Design-Thinking' has supported creative methods in permeating business strategies, and knowledge of 'User-Centred' and 'User-Experience' approaches is now highly sought after. Business awareness and entrepreneurship are staples of many graduates around the world, but for design graduates especially, for whom the creative process is a vocation, an enterprising ethic is essential for surviving in such a completive sector.
In terms of an educational philosophy the current understanding and prediction of future trends in design practice is demonstrated well by Paul Rodgers in his description of the 'polymath interpolator'[1], a term originally coined by Richard Seymour. Partly driven by the Cox review of 2005 [2], Rodgers expands on the notion of multi-disciplinary centres and the potential in education for the development of skill sets that cross traditional boundaries. However, the framework for this has its emphasis on marketing, commerce and economics. While no doubt such acumen is a valuable generic asset in the modern world, it further exposes an omission within design education, and that of polymath tendencies, that include a fundamental knowledge and sense of enquiry in science.
Many aspects of engineering and technical product design are deeply rooted in the physical sciences while designing as an activity is neither accepted as a science in itself nor defined by the application of science [3]. Nevertheless, the outcomes of design practice in these fields are a manifestly tangible link with both the physical sciences and, in most cases, with the arts.
While contemporary thinking on design practice and education may have a political and economic drive, questions still persist as to how science based observation and practices have become so disjointed from design practice? Should the curriculum be changed to address it? And if so, in what

way can we expand on the already broad church of Design to provide a mechanism that spans across more aspects of the sciences?

2 DESIGNERS ENGAGING IN SCIENCE

Historically, the comparisons and links between design, designing and science as an empirical practice have been well discussed. In his seminal work of 1969, Herbert Simon made the profound distinction with the statement, "the natural sciences are concerned with how things are whereas design, on the other hand, is concerned with how things ought to be' [4]. The complete paradox between design and science as a fundamental methodology has prompted attempts to rethink the nature of designing and the proposition of it as a human driven technological activity perpetuated by non-scientific knowledge [5].

Although this can be supported through citing a number of instances of innovation and invention that have surfaced without scientific underpinnings [6], it is without doubt that the perfecting of resulting designs has been through the understanding and prediction of behaviours rather than heuristic approaches. That is to say, by undertaking empirical studies to provide explanations, rather than relying on time consuming and uneconomical trial and error or even tacit knowledge.

While designing may not be thought of as a scientific activity there should be little doubt that scientific enquiry is a valid, if not crucial part of design methodology. Science informed design plays a vital part in the development and improvement of concepts. Nevertheless, while this is incontrovertible with the physical and human sciences it is less well defined for the natural sciences.

3 DESIGN, SCIENCE AND BIOMIMETICS

Within research texts evidence for direct collaboration between designers and scientist, especially those in the natural sciences, is relatively scarce. But of course there have been a number of notable design outcomes that although not necessarily the result of collaboration, claim inspiration from the natural world, including de Mestral's famous, if not clichéd, hook and loop fastener.

The term *biomimetics* seems to have been originally derived by Otto Schmitt in the 1950s as branch of biophysics and its link it with applications of technology. Although largely disregarded until the 1990s, save a few notable applications, biomimetic principles are being increasingly recognised as a route to inspiration for designers in the search for new materials, mechanisms and processes. It is proving to be a means to reach new heights of innovation and efficiency. These include the specifics of reducing viscous drag, engineering tactility, structural mechanics and self-healing properties, naturally sustainable systems and methods in AI.

There is a deepening interest in the field of biomimetic practices within Europe and the USA. Research groups are working towards developing design methodologies, biological ontologies and creative methods like BioTRIZ, a biomimetic version of the very successful TRIZ approach [7].With strong evidence to suggest that designers and engineers can learn from and employ 'nature's solutions' to solve many diverse problems, there is an increasing number of regional and international networks of academics and practitioners that are being set up to support interdisciplinary collaboration. These include Biomimicry UK [8], Biomimicry 3.8 in the USA [9] and the AskNature organisation [10].

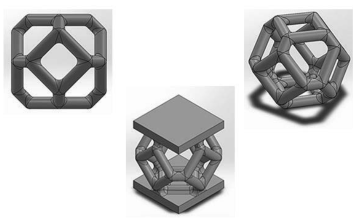
4 BIOMIMETICS IN DESIGN EDUCATION PRACTICE

There follows two case studies each of which explored the possibilities for undergraduates to engage in research methodology that is both scientific, empirical and designerly. The first was aimed at innovative materials and manufacture ultimately for use in bicycle helmets, and involved the analysis and replication of the impact properties of trabecular bone, a natural structure found in specific areas of skeletons. The second example assessed the surface texture application capabilities of additive manufacturing technologies with the intent of providing experimentation in viscous drag reduction. Its purpose was to compare the drag factors of textures inspired by aquatic animals ultimately to explore potential surface coatings for boat hulls.

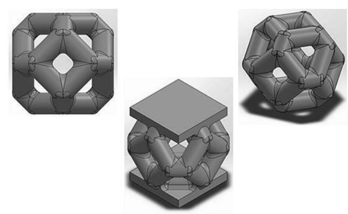
The context of this work centred on final year undergraduate project work, the object of which included the pursuit of innovation in product design. The work itself forms the dissertation aspect of the final year curriculum where students are expected to engage in a valid area of design centred research that elicits primary information. In the case of these projects, knowledge gained from experimental work was used to inform design decisions either in major projects or generic manufacturing problems.

4.1 Education in Mechanics, Materials & Manufacture

Natural trabecular bone consists of a complex network of interlinking rod-like and/or plate-like architecture, and is found in varying proportions depending on the anatomical site of the skeleton. There is significant evidence to support the theory that complex trabecular architecture found within natural bone has impact and shock absorbing properties. The location of trabecular bone occurs in areas of natural skeletons subject to high impact and stresses, where the arrangement of the individual trabecular is oriented according to mechanical stimulus. This study investigated whether natural trabecular architecture can be effectively replicated in samples of laser sintered Nylon as part of an engineered manufactured approach to high impact products such as bicycle helmets.
Trabecular bone was idealised into a hexagonal cell theorised to replicate the natural structure to suit a chosen method of manufacture. The structure was modelled in Solidworks 2013 (Figure 1.A & B), and combined together into flat samples to form a network of interlinking cells sandwiched by 1mm thick plates. Two sets of samples were produced with trabecular thicknesses of 1.0 and 1.5mm, and x, y, z dimensions of 54.5 x 59 x 9mm respectively (Figure2). As a comparison, two other samples were produced excluding the trabecular architecture. These solid samples had identical x and y dimensions, and measured 2mm and 9mm in the z-axis.



A



B

Figure 1. A: 1mm trabecular model B: 1.5mm trabecular model

All samples were subject to impact testing using a falling dart drop impact test (Figure 3). The specific property investigated was the material toughness, or energy absorbed before fracture. As expected the solid samples produced the highest value of energy resistance, but compromised weight and overall cost. The 1.5mm trabecular architecture did not demonstrate significant effective energy absorption or gradual deceleration but the 1.0mm architecture represented a failure similar to that of natural trabecular bone. The individual trabecular at this scale buckles prior to ultimate failure, thereby increasing the energy absorption of the material, and increasing the time to ultimate fracture.

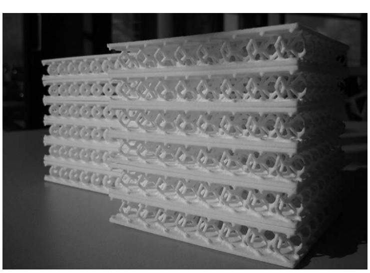


Figure 2. Idealised trabecular specimens

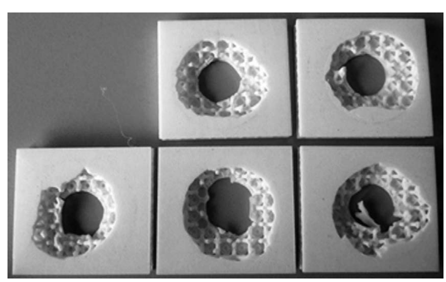


Figure 3. Following impact testing

The study determined that the synthetically replicated structures demonstrate significant energy and impact absorbing capabilities (Figure 4). The information gained from the research was useful in considering the design of impact and shock absorbing components of the product, with an emphasis on efficient use of material mass which could be engineered through the manufacturing process. The final design of the helmet is currently under development and consequently IPR restrictions.

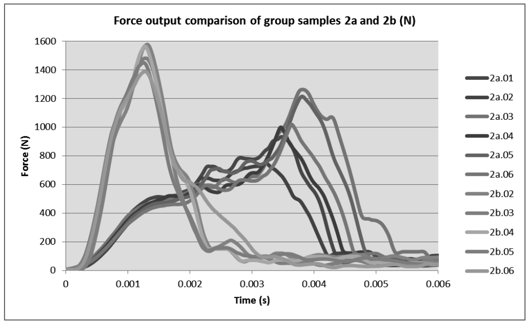


Figure 4. Overall energy absorption results

4.2 Education in Fluid Dynamics & Rapid Prototyping

As in the previous example, the increasing cost effectiveness of additive manufacturing (or rapid prototyping) processes provides opportunities to manufacture products without the traditional constraints of scale. The possibility of creating and experimenting with micro-textures, inspired by nature, becomes more realistic. Such varying textures are found on animal skin and in some cases the nature of the texture is theorised to reduce viscous drag, for example the skin structure of a shark. Within the animal kingdom, aquatic animals are considered to be some of the most widely adapted creatures within their environment. What seems an effortless movement at speed underwater is not only a consequence of the highly evolved muscle groups providing propulsion, but also the streamline form and low surface friction.

For this project the objective was to apply different textures onto the surface of spheres produced via an AM Objet Connex machine scaled at 3 times the original, natural size. Skin details from Shark, Trout and Starfish were idealised (Figure 5) and Creo was used to create the spheres. The experiment itself was simple and well-tried and consisted of dropping the spheres through a fluid of known viscosity and recording the time to calculate the rate of travel (Figure 6). While this experiment may be considered somewhat crude in the age of CFD, the costs and time associated with the necessity of supercomputing power to handle the complex surface structures precluded this possibility.

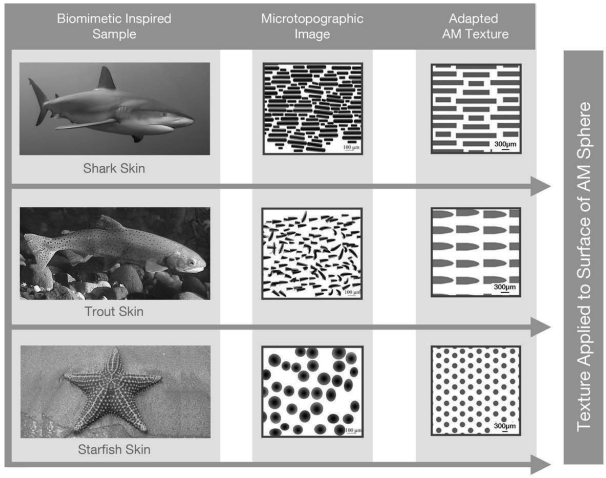


Figure 2. Summary of aquatic surface textures

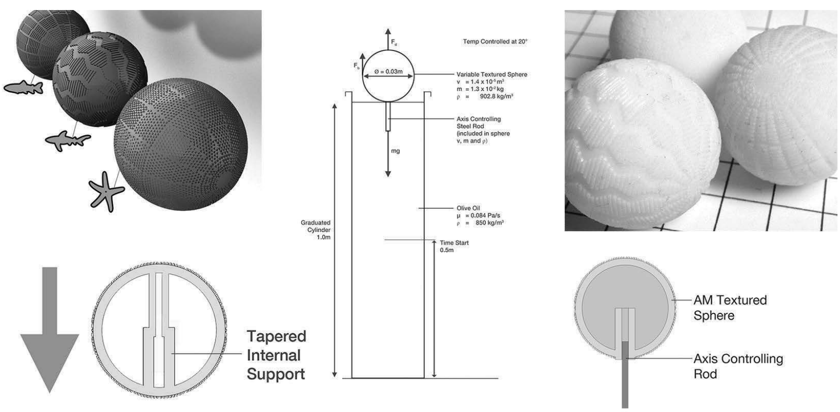


Figure 3. CAD modelling, experimental detail, AM specimens

The results found that in laminar flow, perhaps surprisingly, the starfish skin had the least drag, following the trout and finally, the shark skin. It was suggested that due to the nature of trout and shark, as the Reynolds Number increases, so does the effectiveness of their textures to reduce drag. It was also identified that as the surface area increases, it seemed to reduce the skin friction drag, implying that the surface area improves flow adhesion, which in turn could reduce the amount of flow separation and pressure reducing wake pockets. When the spheres were compared to a theoretical smooth reference sphere, the textures showed an increase of viscous drag of up to 30%. While some of the results were far from definitive and in a number of areas counterintuitive, the data and the hypothesis provided significant input to further discussions for the development of products between manufacturing engineers and fluid dynamists.

The applications for manufacturing a viscous drag reducing texture could range from the hull of a boat to aerofoils to sportswear and even anti-bacterial surfaces. Practical applications already exist including mimicking the ribbed texture of shark skin for advanced swimwear. Indeed, for this project a treatment for the hull of boats that is based on the barnacle repelling texture of starfish already exists, although perhaps unknowingly with the possibility of additional efficiencies.

5 CONCLUSIONS

While there is a constant reciprocating transfer of knowledge between educational institutions and industry, the future of creative Industrial, Product and Engineering Design begins with the education of students. There is currently a strong urge within the HE sector to provide students with grounding in business and entrepreneurship while the underpinnings of scientifically sound problem solving are often neglected.

Encouraging and supporting the development of a broad set of research skills, including those of the natural sciences, offers exciting opportunities to drive surprisingly innovative design solutions. The notion of biomimicry, although currently without the degree of formality of other creative design methodologies also offers the opportunity for problem based learning approaches and to explore new technologies.

Regardless of a scientific background biomimetics can be used to support design students in developing key skills of interdisciplinary working, empirical methods and subject specific knowledge that is both relevant and empowering.

When considering prototype manufacture, the increasing resolution and cost effectiveness of rapid prototyping technologies provides opportunities for the development of products derived from organic structures negated by typical manufacturing constraints.

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ARE WE ASKING THE RIGHT QUESTIONS? RETHINKING POST-GRADUATE DESIGN EDUCATION TOWARDS SUSTAINABLE VISIONS FOR THE FUTURE

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ABSTRACT
Our society is currently facing complex challenges, such us climate change, loss of biodiversity, ageing population, unemployment, to name but a few. This has created growing expectations on designers and engineers to explore, experiment and implement innovative solutions to such issues. At this critical time, if we want design to be part of the solution, we need to wonder whether we are asking designers suitable and sustainable questions. Both in post-graduate design education and in business, the brief still overwhelmingly requires designers to follow a linear problem-solving approach that focuses on product rather than strategies, services and systems. Traditional design briefs result no longer appropriate to face the challenges of our unsustainable world, as they relate to market, growth economy and human needs rather than society, business models and the needs of nature. Instead, we need to be asking questions about, for example, how we overcome the barriers for change, create sustainable business opportunities, and facilitate the process of innovation through design methodology. If the role of design is to create new visions and outline strategic directions towards a sustainable future world - for policy makers, businesses, communities and individual citizens – we need those stakeholders to create briefs for designers that allow them to do that. This paper will explain how the reframing of questions has been embedded into SustainRCA's teaching practice in post-graduate design, art and engineering, leading to the development of new tools and methods, as well as some innovative outcomes.

Keywords: Design brief, holistic sustainability, systemic design, future design education, SustainRCA.

1 INTRODUCTION

We are living under the shadow of a great economic crisis, which will lead to unimaginable disruption of our social and environmental systems [1]. In the last decades, raising energy costs, decreasing resources, tighter legislation and a greater public awareness are creating a fertile ground for bringing sustainability at the core of all design work [2]. This is opening up the opportunity to shape a new kind of designer as driver for sustainable futures, developing new business models, taking radical creative decisions to shape policy and the economy, and engaging society in environmental challenges [3].
Within the rapidly changing world of today, design is consequently becoming a blurry discipline, showing more scope for redefinition, criticality and cutting-edge visions. Academia in the design world has the potential to provide strong leadership in terms of a mature research base, supporting post-graduate research students, contributing to and collaborating with research in related disciplines or professional fields. The UK has proved to have a real strength in service design as a practice, but the research landscape is still emerging and needs to be nurtured with a mindful agenda [4]. There is also an incomplete historical understanding of the development, reach and impact of social design. Furthermore, funding for social and service design is still scarce and often aims at short-term projects, rather than long-term programmes for building new knowledge [5].

2 A NEW ECOLOGY OF THE DESIGN CULTURE

Education will play a key role in creating a critical mass of new design (and non-design) professionals able to drive the transition from a consumerist economy towards a sharing [6] and circular economy

[7] shifting from material consumption to collaborative consumption [8]. This changing paradigm is creating growing expectations among students, academics and professionals. Students are required to broaden their skill sets to face issues outside the traditional remit of design. At the same time, academics are expected to meet students' changing interests and integrate new ways of designing to responsibly drive the transition towards sustainability. In order to implement such a transition, disruptive changes need to invest both academic design education and training for professionals and organisations to adopt a holistic framework and updated design tools to support this changing design scenario. The goal should be a healthier, happier, fairer and more sustainable life, within our environmental limits, while respecting social justice and economic equity [9]. Design briefs must be reframed to address this kind of holistic thinking, considering the four pillars of environment, economy, society and culture [10] in order to achieve economic resilience while improving the quality of our lives and that of the environment. To get there, it is necessary to develop a new ecology of design culture, beyond the anthropocentrism that has traditionally characterised design education and has placed the man at the centre of the universe, valuing all other living beings in relation to their usefulness to us. Instead, a new bio-centrism must be proposed and the worldviews of the designer and audience alike must be shifted. This means acknowledging humans as one species amongst many, all with intrinsic and instrumental values, and focusing on the sustainable interdependence between diverse ecosystems (Figure 1). For instance, this framework was applied by SustainRCA, and independent research unit at the Royal College of Art (RCA), in the Chicken Run project, where user journeys were created for farmers, consumers and also chickens, in order to design and establish a more sustainable and higher welfare poultry industry [11].

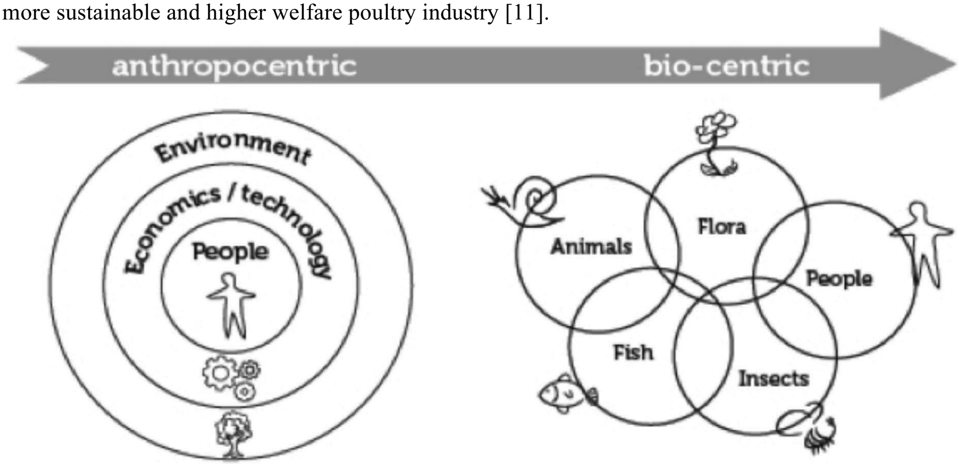

Figure 1. Towards a bio-centric worldview. Source: Rawles, K. [12]

3 EDUCATING THE "O-SHAPED" DESIGNER

Design schools must be primed to train the new agents of sustainability, replacing the "T-shaped designer" [13], having a broad set of skills and specialisation in one sector, with the "O-shaped designer" having a circular and systemic mind-set [14]. To design complex service systems, design education is already embracing students from various disciplines (fine arts, engineering, social sciences, etc.) while addressing a new demand from the market for designers able to work in cross-disciplinary teams. Responding to this demand would help create intelligent and sustainable collaborations between social, political and economic realms, and push the expansion of design research into new domains such as policy-making, public services and circular economy. The designer should become facilitator of a participatory design process, envisioning future scenarios for sustainability and social innovation, collaborating with a complex network of actors. Such a multidisciplinary collaboration can meet the urgent needs for social innovation, while developing long-term platforms beyond final products. The focus needs to be not only on the design of physical things, but on the process and organisational conditions necessary to drive new systems. The designer must be trained to create the "hard" (places, facilities, equipment, technology) as well as the "soft" (network, people and relationships) infrastructures for encouraging such systemic changes.

4 THE DESIGNER OF MICRO-ENTERPRISES

Given the rapid pace of innovation, designers should be primed to intervene at earlier stages of the design process and in a more strategic way to face the challenges of the contemporary world, such as increasing interactivity, connectivity and co-production. In order to face social, environmental and economic challenges designers must shift from a problem-solving attitude towards a goal-focused mind-set, and outline strategic directions to support resilient businesses. Furthermore, designers must be primed to be agile, act independently, with the skills to set up new kinds of social and environmental enterprises. Nowadays, an increasing number of young designers are no longer specialised in a particular kind of production, rather are exploring self-production. Here, a combination of analogue and digital technologies is used, and all the aspects of an enterprise, from design to production, distribution and communication, are self-managed [15]. By designing the complex system of an enterprise, the designer can develop a more mindful and integrated approach to the project, increasing his/her ability to interact with a range of different professionals throughout the process. A mindful example of a young social entrepreneur using 3D printing to tackle environmental issues (i.e. ocean acidification and loss of biodiversity) is the recent RCA MA Innovation Design Engineering graduate Nell Bennett. *Coral3* (Figure 2) is a 3D printed rock, an alkaline substrate structure mimicking fractals and coral shapes. A natural algorithm allows water flow to dissolve the alkaline structure evenly over time, increasing the pH value of the ocean water surrounding endangered coral reefs. This project is envisioned as a large-scale social enterprise involving many stakeholders (from subsistence fishermen to dive tourists) and aiming at providing local communities with economic and environmental benefits, as well as increased awareness [16]. Self-production experiences like this represent the act of "mediation between areas of knowledge" [17], the bridge between craftsmanship and industry, as a response to the current crisis in the work world. The intent of self-production is not to propose a nostalgic return to a regressive craftsmanship, but rather to explore new models of flexible and redistributed manufacturing, and experiment cutting-edge methods with which to challenge traditional sales channels. Such an advanced dimension is being supported by disruptive changes affecting people, spaces, technologies, consumption models and the role of the designer. Nowadays, the access to creative tools is becoming a social prerogative. An increasing number of productive activities, both individual and collective, are being created, fed by the proliferation of FabLabs, Maker Fairs, crowd-funding platforms such as Kickstarter, and market channels such as Etsy. The ideal scenario would be the development of local and interconnected productive ecosystems, sharing resources, tools, spaces and services to co-produce new design practices within integrated networks (involving new kinds of designers, producers and users).

5 THE DESIGNER'S PALETTE

According to Yee et al. [18] the designer should work in a more integrated, collaborative and systemic way and embody the following roles: facilitator, researcher, co-creator, communicator, strategist, capability builder, and entrepreneur. Design language, concepts and methods should evolve to strengthen working skills and mediate between different stakeholders. A new kind of collaboration between designers and businesses under the umbrella of new goals should foster a deep understanding of macro-economic, social and environmental drivers. Moreover, an entrepreneurial skill set must be nurtured, considering and challenging the constraints and potential of the current economic model, while exploring new ones that fit with sharing and circular economies. *Project Phoenix* is an example of user-centric and circular economy thinking from a MA Innovation Design Engineering graduate at the RCA. This labelling and manufacturing system addresses the disposal of small electrical and electronic products in the waste stream. At the end of life, small products can be easily broken into their components with electrical parts sliding automatically into a pre-disposed and labelled bag, ready to be posted back to the manufacturer. In every design project, viability must be considered, as well as scalability in different contexts and growth over time.

In order for new solutions and ideas to be embraced, they need to be explained and pitched in inspiring ways, using all the tools in the designer's palette to connect with the audience. Extensive mapping and visualization skills must be developed further to be able to fully comprehend and incorporate the wider systems implications of all design decisions and to formulate the right question within a brief. Finally, to implement innovation, designers must apply new tools and skills, such as data visualisation, product-service-system design, participatory design and customer experience prototyping.

6 THE POTENTIAL OF SERVICE DESIGN

Within this complex scenario, service design will likely be the key approach to facilitate the multidisciplinary and participatory process with diverse stakeholders aiming at developing collaborative services [19] that are accessible, effective and replicable. Service design is here advocated as the systemic and user-centred process of "prosuming" (i.e. producing and consuming) services that are perishable and based on intangible (i.e. social and cultural) frames and tangible (i.e. technological) interactions [20] [21]. Service design, due to its ability to integrate user knowledge, manage complex situations through prototyping and conduct real public engagement, can support radical changes, increasing both competitiveness and sustainable performance. By designing service systems of people, information and technology, it is possible to co-create value while optimising the material consumption, as well as logistics, distribution, consumption and disposal and trigger social innovation [22]. The shift of interest from the realm of products to that of services and systems is well embraced and boosted by the new MA Service Design programme at the Royal College of Art. For example, Marion Ferrec and Kate Wakely's *Disclosed* is a transparency certification and open data system to facilitate selective shopping by providing customised information, tailored around customers' personal values, such as provenance, health, carbon footprint or ethical supply chain. Although product-service-system design has not proved to guarantee radically reduced environmental impacts yet [23], it has the potential to produce more sustainable outcomes than mere product design, if combined with localization [24], community engagement [25], lightness [26], and changes in consumer behaviour [27] [28]. By adopting service design methods (e.g. shadowing, storytelling, service blueprinting, etc.) it is possible to deeply understand (or empathise with) user needs and evaluate existing interactions or imagine future ones, for more durable product consumption patterns.

7 EXAMPLES OF BEST PRACTICE FROM SUSTAINRCA

In institutions where this transition is already taking place, disruptive innovation is occurring. At the Royal College of Art, where all programmes are 2-year masters level, a department, SustainRCA, has been set up to work with programmes to encourage all students address social and environmental challenges through their work. SustainRCA has helped embed sustainability as one of the core learning objectives across the college, providing support services to students from different backgrounds including arts, science, engineering and design. As a result, in the MA Innovation Design Engineering Programme, sustainability is now considered as a stimulator of creative innovation rather than a constraint and is used as a holistic criterion to assess each design decision. Self-initiated projects begin with a reflection on personal values and are tracked continuously by specialised tutors who provide advice and create connections with external experts. In another context, students are brought together in multidisciplinary groups and asked to find viable and innovative solutions to real-world problems with commercial clients, following a rigorous double-diamond process [29]. The questions are goal-focused, e.g. "*What is the future of mobility?*" "*How can residents of Camden Council take a more active role in creating a cleaner neighbourhood?*" or "*How can we produce meat at current production rates in a sustainable and ethical way?*" Such briefs require students to deeply research the given issue by broadening the emphasis of their design from products to include systems, stakeholders and the relationships between them, and generate briefs and ideas that are viable in the real world. Students explore new economic models and the potential of technology to scale up their innovative ideas within future scenarios based on digital fabrication and economies of scale, sharing and circular economy, happiness and wellbeing, to name but a few. After mapping and imagining future scenarios, students are encouraged to zoom in, exploring users and their journeys in order to define product and service needs of the system. Environmental impacts can be assessed through life cycle analysis tools such as Sustainable Minds (www.sustain-ableminds.com/software) or Eco-Indicator 99 (www.pre-sustainability.com/download/manuals/ EI99_Manual.pdf). To develop and assess their concepts, students are asked to zoom out again to the real world and generate stories to explain their ideas. A palette of tools can support this complex task: for instance, the A420 Index is a mapping tool used to evaluate financial, social, personal and environmental sustainability of design concepts (www.a420.com/index.htm). While addressing systems and global challenges, students are also encouraged to use the C2C Innovator's Toolbox (http://c2ccertified.org), the biomimicry strategies provided by the Ask Nature website (www.asknature.org). Students seek support and share their information and methods in platforms such as OpenIdeo (https://openideo.com) and O2 Global Network of Designers (www.o2.org). Finally, to deliver their designs, students are primed to explore interactions with different stakeholders as well as measure strengths and weaknesses of their outcomes in terms of environmental, social and economic sustainability. Throughout, students are supported by SustainRCA's programme of tutorials, talks, workshops, resources and a wider network of specialists. An important part of the process is to celebrate and disseminate the best examples of sustainability thinking across the College, raising students' profiles and connecting them with future potential employers and investors. For example, a far-reaching series of public-facing discussions about the creative responses to global issues, Sustain Talks, always invites a recent graduate with relevant work to open the event. Similarly, the Sustain Show & Awards showcases the brightest graduate projects from across the College, inspiring new intake of students with a broad mix of ideas for the future. The most successful ideas that emerge from this process are those that start with goal-focussed questions, provoking radical innovations that re-imagine lifestyles and behaviour in the future. As an example, *Ooho!* (Figure 3), a project by a group of RCA graduates, is an open source solution to a Do-It-Yourself packaging. By mimicking the way nature encapsulates liquids using membranes, *Ooho!* is an edible gelatinous structure made of brown algae and calcium chloride grown around a sphere of frozen water. In a cradle-to-cradle approach [30], the disposal of the membrane into the biosphere would provide a nutrient to the soil. This is a provocative concept that starts with the right question to the problem of bottled water. It asks not "*What material should a water bottle be made of?"* but *"How can we carry water with us on the move and have net-positive impact on the environment?"* While carrying a soft bubble of water in your pocket might not seem very practical, it is a short leap from here to the orange, described by Bruno Munari as nature's perfect way of carrying liquid [31].

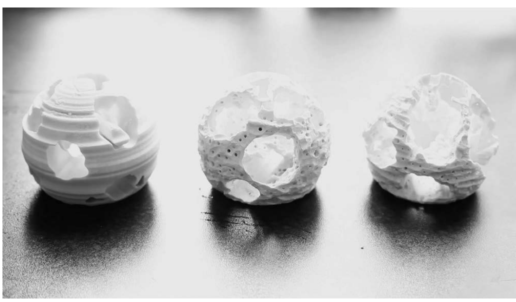


Figure 2. Coral3 by Nell Bennett – Figure 3. Ooho! by Paslier, Couche and Garcia Gonzalez

8 CONCLUSION

This paper suggests that design education is at a critical point: strong growth in student awareness of social and environmental issues, a surge in development in the professional world and interest from new types of clients in the design process has meant that practice is outstripping the research capacity of the post-graduate education design community. Furthermore, there is a growing expectation for design to deliver successful outcomes in response to new challenges, for example from local and central government. Cross-disciplinary collaborations, building cutting-edge knowledge between design academia and the outside world must be encouraged, to re-frame a rigorous research agenda. Overall, there is a historic opportunity for design to lead on the evolution of new economic models that will shape a new ethics of sustainability from a bio-centric perspective, improving quality of our lives and that of the environment. This means moving beyond the anthropocentrism that has long characterised the vernacular of design education, focusing on the co-sustainment between diverse ecosystems. New design briefs must be set, that task students to take on broad sustainability issues, exploring them through visualization and mapping, and assessing the viability and scalability of their ideas according to sustainability criteria. Most of all, design educators need to be setting the right briefs to their students, ensuring they are primed to ask the right questions that push the boundaries of the vision for a sustainable future.

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DESIGN MANAGEMENT

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ABSTRACT
There are many, sometimes conflicting definitions of both "design" and "management". Each is an interplay between physical action in the real world and the mental picture the designer/manager has of that activity. Indeed they have a lot in common, but because of their separate history and terminology, that common ground is lost in a fog of conflicting concepts. When you try to combine them into a single process, "design management", it becomes very difficult to conceive an adequate mental model, which encompasses both parts. This paper will explore this interplay in more detail to find the management knowledge and understanding content essential for designers and design courses.

Keywords: Design management, innovation, organization.

1 INTRODUCTION

A large part of the design task is organizational. It begins with an exploration of the need, which you are trying to meet. Who is the customer, who will finally judge whether you have succeeded? Is it the user, or the purchaser? What are the real needs they are want to satisfy? Who is available to perform the task? Do they collectively have the right knowledge and understanding for the task? How much time and money is available? Who will make the product and how will it be made? These questions, and more, are considerations outside the main requirement of actually designing the product, yet are essential for a successful outcome. These are the tasks of the design manager. My aim is to explore the concepts of design and management to find how they interrelate.

2 WHAT IS MANAGEMENT?

Management is the art and skill, using knowledge and experience, leadership and enthusiasm, of setting goals, planning, resourcing, organising, and monitoring the achievement of an objective, within acceptable limits of cost, risk and time.

Sir Hugh Ford

Modern management thinking began with Adam Smith in the 18th Century [1]. Although his main illustration of work organization was the manufacture of pins, his fundamental message was economic. Management theory since that time has concentrated on the organisation of business with profit as the measure of success. Management is often spoken of as if it were a single definable topic. In fact you can't look at management, beyond a superficial level, without qualifying it as to type and application. Management is a range of similar but separately identifiable tasks, linked loosely by a common theme of organisation.
We can characterise these tasks in three basic ways:

1. **The control of a fixed, or very slowly evolving organisation, set up to carry out a repeated series of definable tasks.** This typically includes most administrative and financial management and often requires a bureaucratic system to ensure that a long series of individual tasks are carried out in accordance with a set pattern of standards. A bureaucracy can be a very effective way of managing such repetitive tasks even-handedly, provided you avoid the inherent tendency for the system to dominate the tasks it administers. Such systems are usually characterised by a set of rules for dealing with all but the most extreme situations. A record of past actions often provides precedence for the interpretation of the rules and, if necessary, the formulation of new rules. Most civil service, legal, and banking tasks typically fall into this category.
   Bureaucracies often lack flexibility but are tolerant of small errors since each case is dealt with as a separate entity with little overall effect on the system. This provides a high sense of security for those staff involved in it. When, in time, large-scale change becomes necessary, it is likely to be

traumatic for both the organisation and the staff and is often resisted. This type of management can be characterised as **“Policy, Procedures, and Precedence”.**

2. **Managing a system where parts of the organisation may change occasionally, but the majority remains fixed for long periods.** The system is also expected to have a long-term future gradually evolving as its role changes. This is typified by large scale manufacturing and most business and sales management, where a number of lines of work may be proceeding together, but each will be replaced in time by others of a similar nature without fundamentally changing the overall organisation. This type of management can accept changes which do not threaten the integrity of the system, but cannot adapt easily to large scale changes and may slowly become outdated. This type of management can be characterised as **“System and Scheduling”.**
3. **The organisation of a change, which has a definable conclusion when the system to carry out the task will cease to have a role.** This is, in broad terms, project management, where there is a specific objective to be achieved. It includes Design Management and even the task of setting up, or changing, management systems for the other two types. (A major example is the rebuilding of Japanese industry after World War 2, guided by the economist W E Deming [4]. His 14 principles have aspects frequently advocated for design management. [See Appendix.])

   A project is often prone to cancellation or external interference and thus has lower security for its staff, further compounded as it nears completion by the inevitable “end of project” insecurity, when staff are moved on and the team breaks up. Staff usually have a far higher sense of ownership and achievement which can compensate for this insecurity. Typically communications play a vital role in completing the task but often the final result is the only record kept. Staff need imagination and adaptability to cope with this sort of task. There is usually a high level of checking and analysis to verify decisions and eliminate errors as far as possible. This type of management can be characterised as **“Communication, Concept, Choice of Options, and Cross-checking.**

Two or even all three of these management types may be found within a single organization. Administrative tasks such as pay, accounting, etc. will be type 1 tasks. Tasks carried out by marketing, personnel, etc. will be type 2. Organizations with a significant forward planning activity will have type 3. With the growing emphasis on business and finance in the last century, it can be seen that, as an organization matures, management thinking tends to move from the more entrepreneurial type 3, through type 2, into the more conservative type 1. As this happens, the organization becomes less flexible, and struggles to adapt to a changing world, being more interested in cutting costs, than in investing in new activities. Type 3 management carries a higher risk of failure, but also has the greatest prospect for opening up new areas of activity for the organization. (This discussion is based on my teaching notes for a CPA Management Short Course for the OU in summer 1992.)

3 WHAT IS DESIGN?

There are many ways to answer that question, but suppose we try a similar breakdown to the one above. Modern design thinking evolved slowly as the products of the industrial revolution became more complex relying on design teams rather than the flair of one imagination, helped by a range of craft support. The two world wars each fostered step changes in the organization of design and manufacturing, which was then carried through to satisfy the post-war needs of an aspiring population. Developments since then have been summarized in the ACED report [2] and papers such as Evbuomwan [3]. Design theory concentrates on the efficient organization of practical concepts, with customer satisfaction as the measure of success.

Design is often spoken of as if it were a single definable topic. In fact you can't look at design, beyond a superficial level, without qualifying it as to type and application. Design is a range of similar but separately identifiable tasks, linked loosely by a common theme of purposeful creativity.

Again we can characterise these tasks in three basic ways:

A. **The routine arrangement of standard parts into a configuration which matches the immediate need.** Examples include: the design of a kitchen layout, using standard modules from a fixed range, to fit the space available; and the “customization” of a new car using the options available from the manufacturer. Usually some form of catalogue lists the options and viable combinations and a vast range of possibilities can be produced from a relatively limited set. (There are over 4 million variations of the Ford Transit van.) This type of design follows on from an original design produced with simple fixed component interfaces in mind.

If an individual combination does not work as well as expected, it does not affect any other project. Occasionally further options are made available, if there seems to be a market demand. Since the arrangement of parts depends on common interfaces for the design to work, any proposals to improve the interface will be resisted, since this may render earlier versions obsolete. This type of design can be characterised as **"Modular, Limited and Derivative."**

B. **The adaption of a known theme or technology to new circumstances.** This can range from the adoption of a common recognizable style for a related range of products (e.g. street signage) to the performance development of a functional product (e.g. the Rolls-Royce Trent series of engines, now considerably more powerful than the original design, with few parts in common). The majority of the design activity falls within this area. For most design challenges, current known technologies can satisfy the functional needs and there are comparable products to help set the human interfaces. Modelling and functional analysis capability is available and there may be standards to guide good practice and satisfy health and safety issues. This gives the designer the security of knowing that a solution is likely to succeed even if it stretches the boundaries of what has gone before. This type of design can be characterised as **"Adaptation and Development"**

C. **The development of a novel form of product where any previous design solution will not suit.** This usually happens when a completely new solution to a previously unresolved or unexplored situation is required, where a current product type cannot be developed further, or when a technological change opens up new design options. When televisions first became more generally available, no-one knew what they were supposed to look like. The introduction of carbon fibre reinforced materials has changed the design of sports equipment, medical prosthetics, aircraft and much more. Type C design carries a high risk of failure, but also has the greatest prospect for opening up new fields of exploration. This type of design can be characterised as **"Novelty and Innovation"**

The size, costs and complexity of the product are unrelated to its position on this spectrum. The costs of the early planning stages are usually only a small proportion of the total and yet most of the remaining costs of the rest of the project are determined then, directly or indirectly. Hence it is a wise investment to make the effort to get these early stages right.

A single complex product may contain two or even all three types of design. It is usually convenient, and economic, to include some standard, "off-the-shelf" components in a design (type A), from fasteners and connectors to larger sub-assemblies. Even in the most novel products, most of the solution is available from existing experience (type B). Rarely, a totally new concept provides a feature which leads to a successful conclusion (type C), even though the rest of the design comes from the other types. Sometimes a new concept (a material or mechanism) actually makes it possible to produce a product not seen before, which opens up a new market. That is innovation.

4 DESIGN MANAGEMENT

- *Design is a process for deciding what to do to achieve a particular objective*
- *Management is a process for deciding what to do to achieve a particular objective*
- *Design Management is not as simple as that*

Colin Ledsome, 1991

There are two aspects of design management: the management of a specific design project; and the management of the whole company design programme allocating human and physical resources between numbers of projects.

Designers are by nature independent thinkers and people aspects of project management can take on a "herding cats" nature. As is usually the case, the best managers are those with experience in the practice, who know when to stay out of the way, and when to concentrate minds on the goal. This is a type 3 management activity of a high order.

Managing the design activity of an organization is a type 2 activity requiring foresight and planning to ensure that each project proceeds at an appropriate pace and each team retains the necessary coherence and continuity of purpose.

The transitory nature of a design project means that historically the learning and experience gained from the project often only remained with the participants. More recently, steps have been taken to

retain a more comprehensive record of the design decision process, particularly those options considered but not taken forward, for future use.
For further guidance on design management see BS 7000 Part 2 [6].

5 EDUCATIONAL ASPECTS

Management or Business Schools tend to concentrate on type 1 management with business at its core. Most design related courses use business schools to provide their required "management" teaching, yet probably do not relate it to the organizational and decision making aspects of design taught as design methods. In 34 years of degree accreditation experience, I have found that most design and engineering students find type 1 management tedious (particularly if it includes bookkeeping), yet will enjoy type 3, which they can immediately apply in their projects. In industry, the major challenges of design management fall into type 3. In courses I would suggest that more effort be put into teaching management as an aspect of design, with the main emphasis on types 2 & 3.
Students often have difficulties with the team aspects of design management. They have been used to being assessed as individuals through their early schooling, so team thinking and the delegation of tasks and responsibilities can be daunting. A design team leader has to transmit their concepts for the product to the group, yet remain open to constructive suggestions. This is a situation where all members of the team can learn. Pragmatic compromise is more likely to provide a satisfactory solution, than the blind pursuit of an unobtainable ideal. Design projects should be formulated to provide opportunities for students to explore these new management concepts, and perhaps struggle a little, before they have to do it in an industrial setting. One approach, which has had some success, can be seen in the CDIO methods [7].
While more general management topics could continue to be taught by business schools or other agencies, design management should probably be best taught alongside design methods. Useful texts are already available, for example [8] & [9].

6 CONCLUSIONS

I have deliberately adopted the same descriptive pattern for both management and design to bring out their similarities. Even so it should be clear that the two topics are closely related. There is an opportunity, for each to learn from the other. (The work of Deming, mentioned earlier, is encapsulated in his 14 rules, listed in the Appendix. It has the clarity of practical purpose and empathetic inclusivity with the practitioners, often found in the best design methods.) The management of design is probably the greatest challenge a manager can take on. Both engineers and product designers spend most of their time in teams, with many contacts in other groups. The earlier they can come to terms with the challenges and rewards this provides, the better they will be.

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APPENDIX

W. Edwards Deming offered 14 key principles for management to follow for significantly improving the effectiveness of a business or organization. Many of the principles are philosophical. Others are more programmatic. All are transformative in nature. The points were first presented in his book *Out of the Crisis.* Below is the condensation of the 14 Points for Management as they appeared in the book.

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive and to stay in business, and to provide jobs.

2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.

3. Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.

4. End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust.

5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.

6. Institute training on the job.

7. Institute leadership (see Point 12). The aim of supervision should be to help people and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.

8. Drive out fear, so that everyone may work effectively for the company.

9. Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.

10. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.

- Eliminate work standards (quotas) on the factory floor. Substitute leadership.
- Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.

11. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.

12. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, abolishment of the annual or merit rating and of management by objective.

13. Institute a vigorous program of education and self-improvement.

14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

Taken from the website of The Deming Institute: www.deming.org

MOVEMENT IN AESTHETIC FORM CREATION

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ABSTRACT
This paper presents the good practice based experiences found when movement is used to strengthen form creation and to create flow in the process of artistic education. Faced with the design engineering students' problems with creating forms with aesthetic statements, the experiences with movement inspired the thesis that the design engineers' training in aesthetic form creation can be improved by integrating the movement potential into their education. The paper documents the on-going work on developing a model for embodied creation of form called 'Somatechne model'. The study also identifies a lens to assess the students' development of mind-body skills, known as 'The Three Soma'. The Somatechne model also helps to identify the activity that gives the students the opportunity to develop their sensibility and thus aesthetic attention.

Keywords: Embodiment, form creation, movement potential, Somatechne model, The Three Soma.

1 INTRODUCTION

This paper seeks to contribute to the solution of the fundamental problem, which was described by Kieran Egan[1] in 2004: "Somatic understanding precedes all others, and persists while our symbolic forms of understanding develop, and it shapes those symbolic forms of understanding in profound and subtle ways. Understanding human cognition, then, requires our careful attentiveness to the body that is their foundation. We have attended to the body's role in our cultural lives and especially in education far too little." [1] Only ten years later, the Danish Ministry of Education implemented a primary school reform with emphasis on the embodiment of teaching subjects such as mathematics and language. Simultaneously, several studies have shown that varied physical movement will cause nerve cells to make new links that strengthen the communications between brain cells and thereby amplify alertness, attention and motivation. And physical movements also encourage the development of new nerve cells from stem cells in the area of the brain called the hippocampus [2]. These studies have been based on human adults up to the age of 64 and rodents. Integration of motion in teaching is referred to as embodiment [3]. The recognition of a need for embodiment in university education has far-reaching implications for how the education is organized and how the study facilities will be selected. In addition, it has consequences for the choice of materials for the form-creating processes, because the form must invoke reactions against the creating force. There will also be a critical need to examine which sort of somatic attention that can be sharpened in order to refine the reflection. In addition, the curriculum and the training should be structured so that it supports the "culturally established ways of paying attention and with one's body in surroundings that include the embodied presence of others" [4], [5]. Due to the limited format of this paper the ethical theme 'bodily interaction with others', which is closely related, will not be considered. The school reform has also been a motivation for this study given that its implementation probably will give rise to future students having a hard time adjusting to the university environment, where teaching will increasingly be based on lectures and stilled seated in groups or at computers.

The present study is delimitated to the problem of design engineering educations that do not focus on embodiment and how this is linked to the students' problems with aesthetic form creation. It has inspired a thesis on how the design engineers' training in aesthetic form creation can be improved by integrating the movement potential into their education. The idea is to identify the first activities in a

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case study of the Billedskolen in Nørrebro[2]'s didactic principle, where movement was included as a key element, especially in the form-generating activities. The purpose is to highlight other facets than those usually offered by design engineering educations, in order to find new movement potentials.
Form creating activities containing physical movement also have the potential to generate flow, which refers to a condition where a person is fully immersed in the activity, "because this activity hogs all the approximately 114 bits psychic energy / attention that is available per second, given that the activity is optimal challenging" [6]. It is typically activities where participants contribute to defining the goals and generating clarity about what to do and thus realise to which extent it is possible to solve the task, with the given skills.
The concept of flow is known among designers who work to transform the latest technological progression to entirely new product categories. For example, the Norwegian multi-artist Pia Myrvold who, in connection with the project 'Flow - a work in motion', explained how she took advantage of flow. For Myrvold flow is to be so inspired that the activities, movements and thoughts merge. Myrvold says that she worked in flow during both the planning and the solution of the artistic, technical and practical problems connected with integrating digital media with mobile technical installations, in order to offer unique experiences [7]. Therefore this study will also focus on phenomenological elements that characterize the flow.

2 THE EDUCATIONAL PRACTICE AROUND MOVEMENT IN CREATION

The separation of mind and body has long been dominant in universities but René Descartes (1596-1650) prepared a way for the recognition "of human beings as necessarily 'embodied' or 'incarnate'" [8]. Friedrich Nietzsche (1844-1900) said: "Contrasting two views; one maintaining 'I am body and soul,' and the other, more enlightened view, which maintains 'I am body entirely, and nothing else beside; and soul is only a word for something in the body'." He elaborates this position further in the following paragraph: "But greater than this - although you will not believe in it - is your body and its great intelligence, which does not say 'I' but performs 'I'" [8].
Maurice Merleau-Ponty (1908-1961) "emphasises embodied perception and the notion of "lived experience". Furthermore, Merleau-Ponty talks of the "body-subject" and emphasises the primacy of perception in our relations with the world" [8]. The spatial perception Merleau-Ponty talks about, was also a key element in Billedskolen's didactic model. Bjørn Bråten[3] describes it as learning through an exchange between susceptibility, reflection and power of expression. In practice, the susceptibility is trained through challenge of both sensory apparatus as motor and balance apparatus [9]. See Figure 1. The theoretical side of susceptibility was trained through research, analysis and discussion. The power of expression would, with Descartes and Nietzsche's words, be the same as the embodied or performed 'I', while partly the movement and partly the generated image set marks in the world.

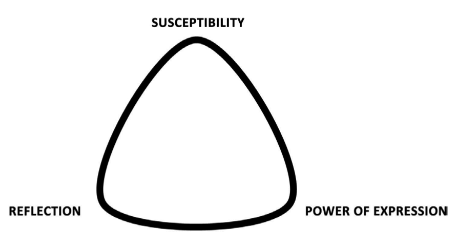

Figure 1. Billedskolen's didactic model

Both the experience from susceptibility and reactions from the power of expression establish a basis for reflection on the form and the creation process. The reflection worked back on susceptibility and power of expression in the form of increased alertness and inspiration. The context and the interaction with others will influence the process and so will feedback from for instance presentations to colleague and to manufacturers or at exhibitions.

2 Billedskolen on Nørrebro (1971-2011) subsequently it changed name to the Copenhagen School of Arts and its educational profile to a more art-theoretical approach at the expense of the technical disciplines.
3 Billedskolen's founder and leader from 1971 to 2011.

2.1 A Proposal for a Model for Utilization of Movement in Aesthetic Form Creation

Judith Davidsons[4] notes that "the learning of an art form is always a balancing act between technique and expression. Technique being the knowledge of skills, materials, history, and usage in the context of practice, and expression the context of evaluation, meaning, and significance in which technique is displayed. Expression is a highly narrative act, embedded in stores and cases that comprise meaning. Technique and expression are interwoven through activity that unfolds in time and space." [10] Art forms are an aesthetics matter and a matter for analyse, which also analyses the techniques behind the creation of art; but all objects that are institutionally categorized as art are not aesthetic and many technical products that offer aesthetic experience are not institutionally categorized as art. Design engineers focus on creating technical products that meet Alexander Baumgarten's aesthetics considerations, therefore the model has to centre on creating forms that either immediately allow for sensory experiences or through interaction with the form [11]. For example, dumper drivers may feel that they have supernatural powers, when they move dirt. The concept of technique involves movement in two meanings of the word:

- The force that masters a tool or leaves traces directly in materials.
- A form with a textured surface i.e. a relic which make up a readable trace.

In line with other people, movement can transform a technology from an experienced to a novice and the rhythm can generate flow in the process. A model for the use of movement in aesthetic creation can be made on the basis of the didactic model and techniques that train motor skills and balance, as well as these senses:

- Susceptibility increases through the study of traces of techniques and practice in the techniques with reflection on perceptions and the importance of techniques for the creation and, if possible traces that make sense in relation to an aesthetic statement.
- Power of expression increases in practice through materialization of the leading feature while the stepwise development is documented and evaluated.
- In relation to the movement aspect, the reflection focuses on the embodied part of the process and the obstacles sought to overcome.

The model is called 'Somatechne' as it is develop by crystallization of embodiment and technical elements from the didactic model. A bit of research shows that the word construction soma-techne is not new; but has been used both to describe body-technique to control technology and technical control the body's functions. The concept soma means the recipient, executive and reflective 'I'. The somatechne model is used as a basis for discussion in following section where I explore the ways the model's three instances appear in form creation in Billedskolen's practice.

3 DEVELOPMENT OF THE THEORETICAL BASIS

Somaesthetics provides a way to "correct the actual functional performance of our senses by an improved direction of one's body, since the senses belong to and are conditioned by the soma. Socrates long ago insisted that the body be kept fit and healthy in order to augment the accuracy and range of our perceptions. 'The body is valuable for all human activities, and in all its uses it is very important that it should be as fit as possiblex'" [12]. Somaesthetics is defined as "a discipline devoted to the critical, ameliorative study of the experience and use of the body as a locus of sensory-aesthetic appreciation (*aisthesis)* and creative self-fashioning" [12]. Self-fashioning is not directly an issue that concerns design engineers, but many of the tools that are used for self-fashioning are. The body's development is then the indirect goal for the effect of such tools. With somaesthetics Richard Shusterman[5] point out that the body is a readable mirror of our mental reactions. For example, a tension can be an expression of a discomfort caused by using a tool.

Bergit Arends has collected a catalogue of the connections between mental reactions and body language, which design engineers use in their usability studies [13]. Søren Kirkegaard also had an eye for the body's movement (human action) as a mirror for mind's movement, as he describes the analytical approach as follows: "I look only at the movements. But I do indeed look at them, and I do not let myself be fooled, either by myself or by anyone else." Design engineer use the same approach

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in order to clarify the true behaviour of the users. The observation of what users do carries with it more weight than what they say they do. For this study Kirkegaard's discussions is interesting because they put the aesthetic reasons for moving above the ethical reasons.
Analytical somaesthetics forms a whole array of interesting knowledge about bodily forms, norms, practices and techniques. Nietzsche observed that man: "does not say 'I' but performs 'I'." This observation is relevant for analysing product handling in connection with documenting a ritual which involves a product. For example, when determining if the ritual of brewing coffee including the roasting and grinding of the beans adds such pleasure to the user's experience that capsule coffee makers will not survive. Somaesthetics also opens up for the aesthetic angle on movement itself and thus on the behaviour pattern in the technique or the body's interaction with the tool. Somaesthetics practice that deals with the active body's physical training in reflective process also maintains and develops the inner sensibility. Somaesthetics' central argument for the embodiment and thus for the movement's impact on form creation is: In order to learn to think "it is necessary to exercise our limbs, our senses, our organs, which are the instruments of our intelligence." And "Somaesthetics (as the term *aesthesis* implies) is concerned with educating the bodily senses (including our kinaesthetic and proprioceptive senses) that are needed to properly direct the bodily powers we deploy"[12]. Design engineers deal with how humans perceive the limbs' location in relation to the body in ergonomics and the body's interaction with machines under the theme: 'human machines interaction' with, at best, considerations of wellbeing. These somaesthetics considerations make it clear that both movement and sensation must be a key element in the somatechne model, if it is to contribute to the aesthetic angle on form creation, while Kirkegaard reminds us of the ethical angle.

3.1 Looking at Movement Potential in the Billedskolen's Practice

The training at Billedskolen was theme based with material and technology testing in combination with form experiments. The program was based building a repertoire through testing and understanding of the impact of the various initiatives to develop form. The students worked with both 2D and 3D sketching while walking or standing by easels instead of sitting or lying with easel plates. A 3D sketch is a physical object in a different material than the final form. Sketching represents both training in techniques, in registering and in exploring the solution frame and the development of form. Because computers can still only interact with the body to a limited degree, they are currently used almost exclusively as an independent visual medium. During 2D sketching the motion gives direction and rhythm to the image while the movement responds back to the body, so that the movement can be felt in the image. In the work with 3D sketches and forms, the student uses the power of movement to create the form and the reaction relays the feeling of the form to the body. The students must constantly move around the form and change the visual angle to reflect on each addition or reduction of it and to counterbalance it. The movement and the resulting power of expression can be observed directly in the process and in the form development. A mental image is not capable of maintaining the experiences of the form as a basis for evaluating its development compared to earlier stages, and give a basis for choosing new initiatives. Therefore 2D sketching or photographing from all angles was used as process documentation along with the creation of new 3D sketches. The documentation also makes visible the student's reflection and together with 3D sketches establishes a basis for discussion. The students also move around in the room when they, on the one hand, reflect upon the impact of the form in the given context and, on the other hand, study the movement of other students' bodies in their form creation. The body's relative movement in space around the form is a prerequisite for the spatial perception during form creation, while, at the same time, the shifts between techniques and materials challenge the senses. The assessment of the student's knowledge and competences was not based on specified levels for each semester, but relative in relation to the student's proficiency at the latest assessment. The development of susceptibility can only indirectly be assessed in the meeting with the student, for as Shusterman writes: "The inner sensibility, that one here generates through one's reflections is harmful. Analysts easily get sick.... One must be self conscious in observing one's own representations and sensations (one feels oneself completely)"[6].

3.2 Looking at the Mind-body Skills Development

Judith Davidson's use of 'the lens' in her method 'The Three Bodies' and Richard Shusterman's somaesthetics raise three important questions for examining that part of design engineer's curriculum, which revolves around the creation of aesthetic form [10] [12].

Davidson's lens was used to record embodied knowledge in art education - in music, visual arts, dance and drama - at grade school level. The lens is a good starting point because while visual arts may include form creation, sound design can also be an integrate part of product design. In addition product design is often staged in connection with presentations. It is necessary to sharpen the lens on design educations and adjust it in relation to the somatechne model. The adjusted lens is called 'The Three Somas' to avoid confusion. The lens three focus points and questions are:

- The individual and physical soma: an instrument to construction and presentation of knowledge through objects. How can the body be used as an instrument for the student's communication of and experience with aesthetic statements?
- Social soma: an instrument to construct the patterns of movement and present persona and interpret other people's knowledge about such personas and movement patterns associated with social structures or groupings. How can students learn to stage aesthetic movement patterns or personas and decode other people's bodily experience of the same?
- The institutional soma: an instrument for the institution's discipline and surveillance – specifically the design profession's regulations and ethical rules. How do the students learn to discipline their bodies' movement in form creation in relation to the educational institution's workshop rules, while maintaining an experimental approach?
  The bodily ethical rules also restrict the students' behaviour in the case of field studies, study trips and when presenting product proposals to the client.

Courses in form creation and design projects will form the basis for exploring the ways in which these three instruments have been used in our design engineer education. Also I will investigate to what extent the institution's facilities and rules allow for the exploitation of the movement potential.

4 INTEGRATION OF MOVEMENT IN A DESIGN ENGINEER EDUCATION

modules in the design engineering curriculum was chosen for the study in order to articulate where movement potential can be embedded either directly or with minor changes to the courses in the form creation of the courses: 'Form and Technique,' 'Form and Surfaces' and the elective courses 'Communication between Collaborators and Contractors', 'Organic Design', 'Exhibition Design and Production of Prototypes'. A similar investigation is made of the mini-project 'Product Design' and the projects 'Analysis of Works and Transformation' and 'Re-Design' and also 'Program and Concept'. It is a special challenge for design engineer students to incorporate usefulness in the product, but that also gives them an opportunity to create aesthetic experiences.

4.1 Individual and Physical Soma

The typical procedure is to analyse the piece of art or design – analysis of form creation with functions and production demands integrated – and presentation of the product with arguments for aesthetic qualities. The courses 'Form and Technique' and 'Form and Surfaces' are compared. The first course works with small 3D sketches in plasticine and the second course works with moulds in plaster and concrete products with a weight up to 50 kg. The three elective courses work with measuring and copy making in heavy craft paper, organically shaped products and prototyping of furniture in steel with weave poly-rattan, respectively. The mini-project needs, just like the course 'Form and Technique', movement potential, because the products are too small. However, they were completely or partly produced in the right wood material, thermoformed plastic or sand cast aluminium or brass. The handling of the product, however, contributes to the development of susceptibility. The projects were all suitable for embodiment when the products were of body size or to be used by the body as is the case for toilets or car seats. Both the course and project modules introduced techniques, just as the students themselves look for inspiration from external clients.

4.2 The Social Soma

Both of the courses 'User-oriented Design' and 'Service Design Method and Theory' as well as the project module ' Service Design' work specifically with 'the social soma', but none of these modules have a direct focus on aesthetic form creation or somaesthetics as such. But the modules help with contribute with tools for recording movement patterns and personas and include work with staging of the service products.

4.3 The Institutional Soma

The institution's frame and very modest workshop facilities have put ever increasing limitations on the physical experiments. The institution's lack of understanding for the value of learning through physical form experiments with a wide range of materials is a challenge. In combination with that the student milieu has not developed a tradition for a self-financiers approach to form creation. Such an attitude could be broken down with inspiration from Polytechnical Association, a student organization at Technical University of Denmark. The association has established its own workshops - electronics, photo, ceramics, wood and metal workshop and a network of contacts to suppliers of material and equipment with discounts.

5 CONCLUSION AND FUTURE WORK

This paper has established a theoretical foundation for the practice-based experience where the movement forces the form creation and generates flow in the process. A model for the embodiment of the creation process has been developed and named Somatechne. 'The Three Somas', which is a further development of 'The Three Bodies', is used to explore the possibilities of embedding movement potential into a design engineer's training in aesthetic form creation. The study reveals that the pedagogical practice in design engineer programs based on problem-based project and group work requires only small changes in order to allow for the need for movement. Big design objects with modelling can take advantage of the fact that movement boosts the power of expression and contributes to inner peace and joy which again generates drive in the modelling process.

In the future 'The Three Somas' should be studied further as a model to ensure embodiment of form creation. Similarly, the 'Somatechne model' should be tested as process model for form creation, particular on the importance of the techniques, which in present study were just was taken for granted.

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RULES AND COMPLEX THINKING IN DESIGN EDUCATION

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ABSTRACT
This article seeks to reformulate the notion of basics as rules within the context of design education. The typical design education curriculum introduces *design methods* as a pedagogical approach. This includes concepts for how to approach goals and the means for how to solve problems or disclose possibilities. Such methods are comparable to the qualities of rules found in games and play, which in turn influence behaviour and mentality. We analyzed introductory course descriptions in design education as they relate to theories on play and game, phenomenology and pragmatist aesthetics. This exploration showed that there is a tendency to define basic knowledge and skills in the very first course in design education. We interpreted this to represent a belief in rules, as in truths, following a possible unconscious establishment of a tradition for the acceptance of certain rights and wrongs as well as automatic behaviour. We argue that such a recognition of rules as a pedagogical platform may transfer to students and represent a subsequent type of culture wherein the students follow instructions rather than think for themselves.

Keywords: Rules and education, play, basics, design pedagogy.

1 INTRODUCTION

Educators both experience and acknowledge that society has problems that relate directly to consumption and subsequently to design. Therefore, they frequently become involved in societal and environmental issues. These interests are often translated later into specialization courses in design education. Hence, handling complex thinking, social change and the global environment have become standard terminology in the learning outcomes in course descriptions formulated by educators who often have a design or art background. This implies that the educators are confident that designers can create benign solutions for indigenous people, malnourishment, for example, in social, cultural, psychological and biological contexts, among others, by acquiring what is believed to represent *basic* skills and knowledge, such as manufacturing, design methodology, and form giving. This in itself represents an interesting discussion. However, an even more interesting discussion that emerges from this setting concerns the pedagogical perspective that embraces the idea of something being basic. The so-called basic courses are built upon an ideology, and prepared with contexts and facts ready for the student to explore. Thus, they serve as an extension of the belief in rules and certainties as a pedagogical approach. Nonetheless, it is possible that in their effort to bring more meaning into design education curriculums, the educators are not aware of this positivistic stance as a fundament of their own teaching.

Designers, artists and engineers typically develop and operate the design education programs in Europe. Therefore, the pedagogical stance and educational content emerge from these disciplines. Accordingly, courses are developed and frequently inspired by traditions from early modernism and Bauhaus, which involves an emphasis on practical training in workshops with materials similar to the ones used in manufacturing as well as formal studies in colour, form, composition, etc. For the most part, these courses focus on what is believed to be basic knowledge and therefore often come in the very beginning of a design education program. Thus, without consideration of a context for the work, since this is given, non-existent, or not questioned, the students, for example, exercise to attain skills in drawing, the use of workshop machines, and routines with various design techniques. With these considerations, we formulated the following research question to explore how such an objectivistic pedagogical stance influences the work of students in design education: How can the idea of *basics* in design education influence the students' understanding of their own profession and its role in society.

2 METHOD

We performed a manual context mapping of study plans from Northern Europe to explore how rules, as a facet of teaching the *basics* within design education, potentially influence learning. Introductory courses were the object of this analysis. The empirical data were visualized using word cloud mappings, done with the web-based program *Word-it-Out,* in search of repeated words. This was done to establish a possible core pedagogical stance that these descriptions might contain. Because of the obvious weaknesses in the use of automatically generated word clouds as a method, the word clouds are used to both supplement and to visualize the research performed in this study. We analyzed the findings from the perspective of theories on game and play, phenomenology and pragmatist aesthetics.

3 FINDINGS

We analyzed the introductory course descriptions at five different universities in Europe. We found that they had a common emphasis on basic skills and knowledge. All of the descriptions of the introductory courses present the idea of basics for design education. Design basics are described as

the current gulf between design practice and

ciplinary working has been a well-established
he late 1960s. Since then the design of tangible
riven by competitive business, market driven
inception of 'Design-Thinking' has supported
and knowledge of 'User-Centred' and 'User-
Business awareness and entrepreneurship are

Figure 1. Word clouds illustrating introductory course descriptions at five different universities in Europe

something that exists or that are fixed and furthermore needed in order to practice and learn, not something that the student attains. Therefore, the understanding of basics presented in these course descriptions involves the recognition of rights and wrongs in design education. The course descriptions contain several statements about basics for design education such as; 'The ability to be creative is basic for an industrial designer' [1]. Furthermore, a learning outcome formulation presents the idea of the possibility to attain 'basic skills in the development of ideas for a given context' and 'basic understanding of form and idea development' [2]. It is noteworthy that the introductory courses have limited curriculum materials with books or articles for the students to peruse. In general, none of the introductory courses refers to theory or literature to inform about the relevance or origin for the course.

4 BASICS

We disclosed three main understandings of the basics in the introductory courses. These included the ability to identify the basic differences within culture, theory, etc., to attain a foundation (basics) to perform a discussion and lastly to be informed about basic skills or knowledge, such as in composition. One main difference in these understandings of the basics is that the first two handle the basics as a dimension or object for analysis and further understanding, whereas with the latter, you are taught what basics are (as in a mathematical tradition).

5 PLAY

Rules are an important part of play. Play is defined in various disciplines; from evolutionary and psychological perspectives, it is frequently seen as a way of preparing for life [3]. These perspectives are typically oriented toward the consequences of play and the purposes that play serves, such as obtaining skills, and not what 'play is in itself' (Huizinga, 1955, p. 3). Within the boundaries of play or rules, a player would indeed ruin the game without serious intentions [4]. A high degree of seriousness involves the participants taking risks. Moreover, 'it is the risk that makes play attractive' [4]. Huizinga emphasizes play as a voluntary and 'free activity standing quite consciously outside ordinary life, as being not serious' and 'fun' [5]. Free, in this context, is understood as voluntary but not free from influence.

Caillois's work, which builds on Huizinga's *Homo Ludens,* categorizes four different dimensions within a game, see Figure 1 [6, 7].

Table 1. Caillois categorization of games

Games	Action	Condition	Main property
Agon	Challenge	Rivalry	Contest
Alea	Gamble	Tremor	Chance
Mimicry	Imitation	Simulation	Disguise
Ilnixx	Frolic	Vertigo	Balance

6 RULES

In this paper, we distinguish between a general understanding of the rules, which can be found in play and games, and rules as implemented traditions in education; and, as such, perhaps not acknowledged as *rules*.

Rules in education are frequently used as a context for confined and steered play to happen by, for example, narrow approaches, demands for open ended features, and forced relations to achieve 'guided reinvention' or enhanced and in depth creativity [8-12]. In this study, we understand such rules in education as pedagogical approaches or traditions within the design profession such as, for example, the Bauhaus approach. Furthermore, we understand these traditions to involve and not to question or change the skills they are believed to elicit. Accordingly, we understand them to represent the ideology of an educator, which one may assume are, to a large extent and possibly unconsciously, transferred to students.

The use of constraints as a technique to attain creative solutions and form giving is widely discussed and acknowledged in design research [10-13]. However, within this discussion, it is important to make a distinction between the maker perspective and the spectator perspective. Mikkel Tin, who explored rules from a maker perspective in his book *Spilleregler og Spillerom): tradisjonens estetikk* (*Rules and*

Play Space: The Aesthetics of Traditions), proposed that 'rules free the artist from responsibility' through limiting personal choices, which further 'makes a space for play' superior to the space that emerges by an autonomous process. John Dewey, who was interested in the spectator facet of experience, described resistance as a vital part of an experience for it to be whole; furthermore, that it can work as an 'invitation to reflection' [14] and further still lead to 'a higher complexity of thinking' [15]. Therefore, both describe a variation of emancipation. This distinction is to clarify our emphasis for the discussion in this article, which is at the intersection between education built on the recognition of basics, personal choice for students, and resistance as facets to reach a higher complexity of thinking as a design practitioner.

Dewey found it important to give people the possibility to make mistakes as part of their education and that restricted school activities hinders this. He also emphasized how one can learn to understand things more holistically and refuted the strategy of trying to 'make learning easier by breaking down something into separate parts and then assuming that the children will understand the whole' [12].

7 REFORMULATING THE NOTION OF RULES

Here, the discussion is oriented toward the research question: How can the idea of *basics* in education influence the students' understanding of one's own profession and its role in society. Based on the above definitions, it may appear that rules given by educators actually serve as *resistance* (Dewey) and make *space for play* (Tin). To discuss this concept, it is necessary to look deeper into the background for how introductory courses that present basic skills came into being. We do this by looking at theories on play, games and phenomenology.

7.1 Body and mind

The phenomenological view that the body and mind together is a source for experience and further understanding is similar to the processes initiated in today's study programs as well as to the Bauhaus pedagogy. As such, the statement by Descartes, 'I think therefore I am' is refuted and Edmund Husserl and later Merlot Ponty's 'I can before I know' or 'I can converse with the world through my sensing and vigorous body before "I think" world' [13-16] are embraced. Such a view emphasizes the importance of the body and senses as part of cognition and creation. This involves practicing skills until they are made 'automatic' to make space for play [14]. Nonetheless, it does not necessarily elicit situations of innovativeness, absorption, exploration, considering or playfulness if the context and goal for the work are given [14]. This might be one reason for the undisputed belief that basic skills and knowledge exists, which this research has revealed.

7.2 Play and automatic behaviour

Huizinga states, 'as the opposite of aesthetics is not ugliness but apathy the opposite to play is not seriousness but the automatic' [5, 7]. Accordingly, playing within the understanding of Huizinga with something concrete and experiential stimulates understanding. However, to prevent automatic behaviour demands a certain autonomy in *how* one plays. Nevertheless, as Katya Mandoka argues, based on Lakoff and Johnsens, 'the cognitive function' of metaphors is a 'projection of something concrete and experiential to understand something more abstract, is closely related to play [7, 17]. Mandoka therefore suggested Peripatos (explorations) as a fifth classification to Caillois's categorization of games, which entails exploration, as in 'what if,' to be a central facet of games (table 2).

Table 2. Katya Mandoka's contribution to Caillois's categorization of games

Peripatos	Exploration	Adventure	Conjecture

Therefore, when the student is not given the opportunity to explore cognitive and practical dimensions in a holistic (complex) context, they are steered away from the opportunity to explorative play and thus from reaching a higher level of understanding [18]. Hence, when the rules set by an educator serve as defined and unquestioned *basics* for a discipline, the means to understand the problems and possibilities involved, the reasons and goal for the study, etc., the student is left with merely performing automatic skills to model the thoughts and goals of the educator. Consequently, the student does not develop beyond the level of the educator and is instead held back and perhaps even misguided.

In consideration of the findings of Mandoka and Huizinga, the idea of play, rules and basics as part of design education should therefore be questioned. This leads us to suggest that students can benefit by making their own rules for how and what to design. In doing so, they will not only create and modify within a certain play space but also propose *to* and *how* to alter and create the play space itself. Therefore, when the students no longer have to acquire skills or acknowledge the rights and wrongs, design might become a free activity liberated from the ideology of the educator. Given the opportunity to think by themselves, the students might be able to engage with serious intentions and take risks as well.

7.3 Rules and basics as a pedagogical stance

The tendency disclosed in the introductory courses in design education involves the belief in basics as a pedagogical stance. Basics lead to teaching rights and wrongs and is followed by drilling the students toward automatic behaviour (Figure 2). Such pedagogy represents an objectivistic epistemological perspective. Accordingly, when one, for example, presents the basics by formal form studies or workshop learning in introductory courses, the students will be supplied with specific skills, but they will also be supplied with ideology pertaining to design rules and facts.

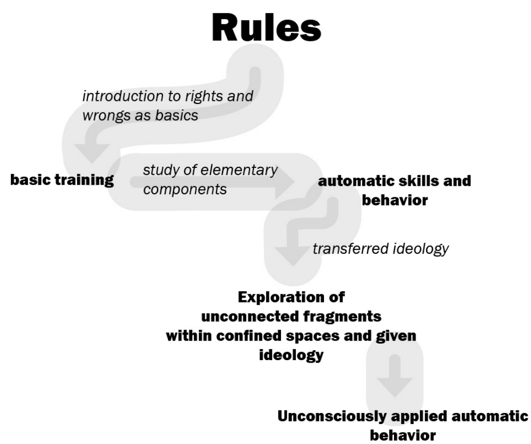

Figure 2. Rules and basics as a pedagogical stance

Thus, when the educator liberates the students from the possibility of making choices and performing critical thinking by drilling skills, design methods, discussions and goals, as unconnected fragments of a whole, the students must rely on the educators to be told what is interesting and important and how the presented problems must be solved by the rules. We question whether John Dewey's main emphasis with the concept of learning by doing is misunderstood with the embracement of basics and automatic skills by many educators. While Dewey emphasized learning from experience, this was not without further reflection after doing or experiencing [12].

If the primary goal is to have students who can acquire skills and knowledge to map, understand and design for complex situations in society, one should think that letting the students in on defining what is important and what rules to follow in a design project would enhance the ability of those students to think critically by themselves. Nonetheless, to prevent automatic behaviour demands a certain autonomy in *how* one plays.

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Chapter 2

Collaboration

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
3 & 4 SEPTEMBER 2015, LOUGHBOROUGH UNIVERSITY, DESIGN SCHOOL, LOUGHBOROUGH, UK

COLLABORATING ON A CASE-BASED COURSE IN QUALITY MANAGEMENT AND CONTROL

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ABSTRACT
Quality Management and Control is a fourth year technical elective course focusing on analysis, evaluation and improvement of processes and designs. It has been taught in a conventional manner using lectures, assignments and exams for several years. The instructor, who is also one of the authors, was asked to teach this course for the first time and wanted to stress the real world importance of quality control in engineering design and provide students with realistic applications of quality management techniques. For this reason, the instructor chose to present the theoretical part of the course during the first half of the term by traditional lectures but use a case study approach for the second half of the term. Multiple available cases were reviewed for general alignment with the course objectives, and three case studies were chosen. The instructor then worked with the case-writing group to create case assignments to supplement the original case study, and concentrate student discussion around specific course objectives. There were several challenges associated with creating this case-based course. These are presented as well as the development process, implementation strategy, suggestions for improvement, student feedback and instructor observations.

Keywords: Case studies, engineering education, deductive approach, inductive approach.

1 INTRODUCTION

Traditional engineering education uses a deductive approach: an instructor explains theoretical concepts through lectures and then follows with applications and an examination. This is a teacher-centred approach which has many benefits; however, this method typically omits the motivation for students to learn course material. A deductive approach can also make it difficult for students to realize the importance of the concepts being taught. Inductive teaching, on the other hand, is one way to instil motivation and expose the importance of theoretical concepts [1]. The case method is an example of this approach. A case study is a description outlining the complexity and context of a real-world challenge faced by a particular decision maker. It requires students to analyze the problem and make a decision in the role of the original decision maker [2]. An important aspect of a case is that there are multiple solutions; this allows students to increase their tolerance for ambiguity [3]. By exploring problems and various solutions, students are inspired to use creativity and innovation [4]. The case method also encourages students to participate in activities, as opposed to the traditional lecture method. Students are known to learn more effectively when they are actively involved with their learning and it challenges them to accept responsibility for their own education [3]. Although the case method has been proven effective, it is not prevalent compared to traditional lectures in engineering education [4]. With an increasing emphasis on outcome-based assessment criteria by the Canadian Engineering Accreditation Board (CEAB) [5], there is a need to implement pedagogical methods that work towards these goals. As preparation for the workplace, case studies were used in a Quality Management and Control (MSCI 551) course in an attempt to give students the opportunity to practice using quality control in engineering design. This course is a final (fourth) year technical elective as part of the Management Engineering undergraduate program at the University of Waterloo.

2 OVERVIEW OF CASE DEVELOPMENT IN MSCI 551

MSCI 551 focuses on the analysis, evaluation and improvement of manufacturing and assembly processes in order to increase quality. The overall objective is for students to be able to incorporate quality control during the design of a manufacturing or service system, which is a significant aspect of the Management Engineering curriculum and of management engineering design. The major topics of

MSCI 551 include process capability analysis, statistical process control, experimental design and acceptance sampling. During the Spring 2014 term, the course was redesigned by a new instructor. Students were introduced to quantitative methods and fundamental concepts in the first five weeks using traditional lectures and then, throughout the remainder of the term, learned new qualitative techniques and applied all methods and concepts to a series of case studies. The instructor chose case studies because she wanted a higher retention of information and an opportunity for her students to integrate multiple concepts. By developing an implementation strategy using case studies, students applied both quantitative and qualitative methods in the context of real world designs and processes.

2.1 Case Selection

The teaching objectives for the course were used to guide the case selection process. The cases were chosen from previously developed case studies by Waterloo Cases in Design Engineering (WCDE), a group on campus that creates case studies for use throughout the engineering curriculum in order to enhance learning. The selected case studies had to include sufficient context and complexity that would allow students in MSCI 551 to:

1. Accurately summarize aspects of a quality management system
2. Confidently assess a system for quality improvement opportunities
3. Design and evaluate a quality management system for a process
4. Successfully apply documentation and analytical techniques related to quality
5. Effectively communicate about quality management systems

The cases were also selected by considering the presumed students' areas of interest, since this can increase their engagement [4]. The problems related to the current world and to everyday business. The purpose of this was to show the relevance of course content at a level of complexity that appropriately challenged the students [6]. Multiple cases were reviewed and three cases were chosen (Table 1) based on the instructor's evaluation of the cases' connection to the course objectives.

Table 1. Case studies selected for MSCI 551 and their respective problem statements

Case No.	Case Title	Original Problem Statement	Targeted Course Concept(s)
1	2008 Canadian Listeria Outbreak [7]	The design of the food safety system and regulatory policies at Maple Leaf Foods needed to be studied for shortfalls and for improvements to prevent a similar incident.	Statistical Process Control Continuous Improvement: - DMAIC[1] [8] - Six Sigma
2	SteriPro Operations Analysis [9]	An opportunity exists for process improvements that best achieve optimal reprocessing volumes. This new process had to meet design constraints as well as relevant regulations and standards.	The impact on quality in product and process design: - PDCA[2] Cycle [8] - Quality of process design - Quality of product or service design
3	Sleeman Bearing & Gearbox Failure [10]	There is a need to investigate the design of a gearbox following bearing failure in order to determine detection methods to prevent future failure.	System Maintenance/Reliability - Lean Maintenance - Preventative, predictive and proactive maintenance

2.2 Case Assignment Development

The selected case studies were originally created for other courses or had slightly different learning objectives. Therefore, the focus of each case did not necessarily fit MSCI 551. To correct this, the instructor outlined a new problem statement for each case that was more specific to the course material. A WCDE staff member used this to create a supplemental case assignment. In some instances, certain information was missing that was necessary for students to solve the new problem statements. WCDE staff procured this information by directly contacting the industry partner with

[1] DMAIC stands for Design, Measure, Analyze , Improve and Control
[2] PDCA stands for Plan, Do, Check and Act

whom the case was originally developed. These assignments forced students to analyze designs and processes for failures or weaknesses. Afterwards, the assignments required a redesign of the original process to prevent a similar failure or create an improvement. This is a valuable aspect of engineering design since quality control and continuous improvement are constantly applied in industry and need to be emphasized to students during their undergraduate career.

3 IMPLEMENTATION STRATEGY

There are multiple ways of implementing the case method, each varying with the instructor, course, and case study. However, there are some basic implementation practices that are highly recommended, including giving time for individual student preparation, small group discussions, and large class discussions [2]. It is also good practice to give consistent evaluation and feedback when using multiple cases [2]. Table 2 summarizes the implementation steps, student reactions, and instructor comments. The students were first asked to individually read a case and the associated assignment, and then complete a comprehension quiz. Small group discussions followed by full-class discussions were employed to create an engaging atmosphere for examining multiple solutions. Students self-selected groups of 3 or 4 and gave short presentations to receive feedback from their peers and instructor as preparation for a formal report. The same groups were used for all three cases and they presented a solution for each case study during which they had to justify their decisions.

Table 2. Summary of implementation steps used for each case study

Step	Description	Samples of Student Reactions	Instructor's Comments
1	Individually read case study and reflect on problem statement	"It was much better than reading concepts out of the book."	They need to read on their own in order to contribute to group discussions.
2	Small comprehension quiz (students given 10 minutes to complete)	Not applicable	This was important to motivate students to individually read each case.
3	Small group discussions (not asked to reach a consensus on a solution)	"It was easier to see other perspectives of the cases which ultimately sparked new ideas."	This step was helpful to bounce ideas off each other and clarify information.
4	Large group discussion (mediated by instructor)	"The class discussions were the best. It was an open discussion and it let everyone bounce ideas off each other and not just one person talking."	Discussing cases created a more fun and engaging classroom environment than a traditional lecture.
5	Small group presentations on proposed solution	Not applicable	These were interesting to hear since each group created a different solution.
6	Feedback on solution by instructors and peers	Not applicable	This step was just to make sure the students were on track for their report.
7	Formal report on case solution	"The case studies in this course gave me a better understanding of course material because I needed to incorporate course concepts for the quizzes and reports."	It was great to confirm that the students learned the theoretical material since they were able to apply it to the cases in a formal report.

3.1 Collaboration with Industry

Two industry representatives from Sleeman Breweries, Guelph, provided extensive support on developing a case assignment for the Sleeman Gearbox case study [10].They provided more detailed information regarding their facility to help students solve the refined problem. Their company hires many engineering co-op students from the University of Waterloo, so they had an obvious incentive to participate. The representatives' enthusiasm towards the case method was evident as they reviewed each student presentation and offered insight to the solutions based on their industry perspective.

4 STUDENT FEEDBACK

A student survey was conducted near the end of the semester for continuous improvement. The baseline for comparison was the lecture component of the course used in the first half. The same students were exposed to two teaching methods and were asked to self-reflect on their ability to appreciate and understand course concepts using case studies compared to the lectures. Questions included self-evaluations of student understanding and ability to apply the concepts, opinions on each case study, and suggestions for improvement (Figures 1 and 2). The overall response from the students was very positive. There were numerous comments that they enjoyed real life applications and the instructor's use of the case method. Students appreciated that the case study activities connected to real life, and therefore demonstrated the importance of the course concepts.

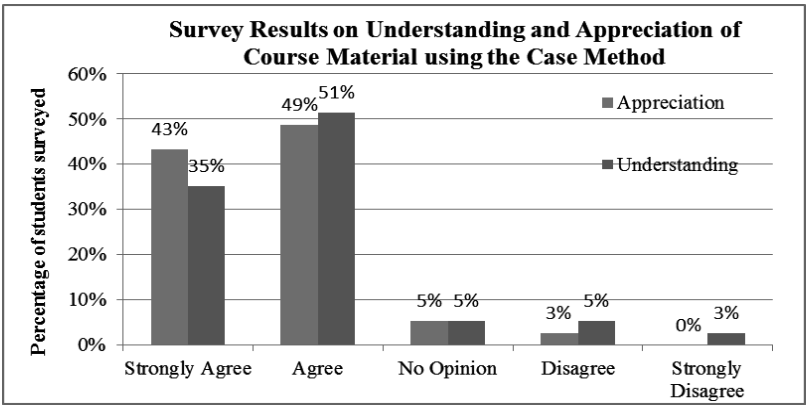

Figure 1. Student feedback results based on survey questions "Did the case studies give you a better understanding/appreciation of the course material?"

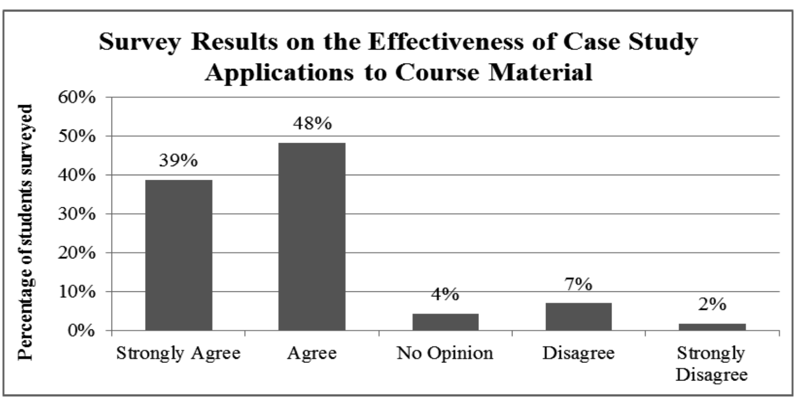

Figure 2. Student feedback results based on survey question "Were the case studies an effective application of course material?"

Figure 1 indicates that the majority of students agreed that the three case studies gave both a better understanding and appreciation of course material. There were numerous student comments that the cases showed real world connections which demonstrated the relevance and importance of course material to the workplace. Student comments suggested that the basic understanding of concepts came directly from the traditional lectures, but the cases forced them to think more deeply about course concepts through application and design. The students who disagreed in Figure 1 felt that the case studies were either too open-ended, there were too many assumptions, case topics were not interesting, or the cases did not improve their understanding of the course material.

From Figure 2, the majority of students again agreed or strongly agreed that the case studies were an effective application of course material. Students provided feedback that the applications were interesting, connected to relevant real-world problems, and they were able to use course concepts to generate a solution. Most comments by the minority of students who disagreed with this question said that they were not interested in the specific application or that they felt that certain cases did not allow them to apply techniques from class.

Formal course evaluations are conducted for all undergraduate courses. The instructor was rated highly overall for this course. Specific categories that were rated high, and pertained to the teaching approach, included an appropriate level of complexity, organization, professor-class relationship, and the contribution of assignments to create a better understanding of concepts.

5 DISCUSSION

Case-based instruction has been used numerous ways in engineering curricula, with positive results in the literature [11]. The instructor for this course observed that the learning environment was more engaging and interactive when the case method was used, compared to traditional lectures. This aligns with other studies and is attributed to an active-learning component as well as collaborative learning [1]. Although the MSCI 551 class was more engaged using cases, the traditional lecturing was pertinent to the students' understanding of fundamental concepts and should remain in the course design. A recent study showed that students preferred traditional lectures for developing a better understanding of concepts but, compared with cases, they were much less engaged and less active [11]. This study, as well the course structure in MSCI 551, suggests that students learn best when these methods are combined. Traditional lectures are effective at providing comprehension of concepts and the case method is effective at engaging students in applications of these concepts.

A national survey in the United States asked science faculty members their perceptions on the benefits of cases. The vast majority of faculty members agreed that cases improve students' critical thinking, encourage the development of deeper understanding of concepts, enhance engagement, provide students the opportunity to actively be involved in their learning, and integrate multiple concepts [12]. This was also evident in MSCI 551 in the quality of the formal reports. The reports demonstrated the students' capacity to incorporate quality control concepts to the context of a case study. The quality and level of effort, as well as their enthusiasm during group presentations and class discussion, reflected their engagement. During the MSCI 551 implementation, students successfully used multiple concepts to justify their decisions in the solution of a case problem. This success is partially attributed to the development of a case assignment. This was an important strategy for implementation in MSCI 551. It narrowed the scope to directly relate the case to the course teaching objectives to ensure that students focused on applications of course concepts.

The students were observed to be more thorough with their solutions when they knew industry representatives would listen to their presentation regarding a problem that was derived from the industry's facility. Students found industry feedback very insightful. Many of their solutions lacked a practical perspective; they relied heavily on their academic background and theoretical concepts. This was despite the fact that they had already completed five co-op work terms as part of their academic program. Industry feedback pushed students to think more about the context of the case and how the implementation of their solutions could present challenges in the workplace.

Not every student liked all case topics and some did not find the cases to be an effective application of course material. There was a common trend that negative feedback in the survey correlated with comments that suggested a lack of interest in the case study topic. Although engagement does not increase problem-solving abilities, it is suggested that engagement and interest in the topic makes students more willing to put in the effort to apply multiple concepts and provide a quality solution, which ultimately creates a deeper appreciation and understanding of course material. However, the percentage of students in this category was small; it is difficult to find a topic that is interesting to every student within a course. This also emphasizes the need to have multiple cases, covering an assortment of topics, in order to interest various students as well as demonstrate different applications.

The main suggestion for improvement based on student feedback was to make the case studies less open-ended and provide sufficient information such that assumptions would not be necessary. This conflicted with student feedback on the course evaluations that the class was highly organized with assignments that contributed to their understanding of concepts. Although an appropriate level of guidance should be expected from the instructor, this inherently goes against the case method as well as design. Therefore the request for less open-ended problems could instead mean that the students are intimidated by case studies even though they are indicative of the workplace.

5.1 Applying this Approach Going Forward

It is clear that lecture and case-based methods are complementary and beneficial to student learning. It is recommended to introduce theory by traditional lecturing and then use the case-based method for integration of concepts and applications. This teaching strategy uses cases to reinforce course concepts that have been covered at the beginning of the course with lectures. Instructors can also create case assignments that require integration of multiple concepts. This allows concepts in the course to build on each other and to be applied simultaneously to a realistic problem. The case-method ensures that these problems have real world context and complexity to further highlight the need to integrate concepts and use problem-solving skills in the workplace. The choice of case is important. To widen the case options, it is possible to select a case study with a problem and context that generally fits the course, and then focus the scope on specific learning objectives using a case assignment. If possible, it is also recommended to invite industry representatives to listen to students present their solutions, and provide feedback. It is not necessary that these representatives are from the same company; if they are within the same field, this industry connection will incentivize students to problem-solve and correctly apply course concepts so that they can be confident in front of practicing professionals. This strategy worked well in MSCI 551 and showed that there are other incentives for students besides grades.

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VISUAL COMMUNICATION OF DESIGN PRINCIPLES IN A COMPLEX KINETIC CONSTRUCTION

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ABSTRACT
Design students need to be able to build a bridge between their own practice and the various receivers of their messages. Studies in design practice confirm that visualisation is a powerful communication tool often used by artists and designers. Despite these studies, a knowledge gap was identified concerning how design principles of concepts and quantitative structures can be communicated to engineers concerning complex and kinetic art constructions. Through a case study of a cross-disciplinary collaboration, a complex and technological public art sculpture was developed cooperatively with various professionals. The main concept for the sculpture project was to use the airflow from two ventilation systems. Based on this process in a real-life situation with objects that can lead to a situation of failure in the materialisation of a project it is discussed how two different disciplines can have discipline specific languages and further it is discussed what kind of competence that can contribute to communicate in a productive way. The discussion concerns the representation of an idea through a tangible model in different traditions and cultures. Such a communication process was visualized as a pedagogical concept for cross-disciplinary communication. Students can benefit from being prepared for these kinds of situations in collaborative design practice.

Keywords: Communication, cross-disciplinary collaboration, language games, cultural differences.

1 INTRODUCTION: DISCIPLINE SPECIFIC LANGUAGES

Design students should be prepared for cross-disciplinary collaboration. Communication across professions is a challenge because each profession has a specific type of language [1]. The philosopher Wittgenstein introduced the idea that language alone can seldom capture the total meaning of a concept because language is often rooted in a certain kind of practice, and he therefore introduced the concept of 'language games' [2]. Language games are connected to how people act as a part of their communication. Collaboration in practice can promote creativity and innovation in professions such as design and engineering [3]. There are benefits of collaboration in design and engineering through cross-disciplinary communication, and these are connected to understanding language games in different work cultures. The anthropologist Geertz points to how we should try to enable competence to interpret other cultures and thus better understand cultural differences [4].

2 BACKGROUND: NOISE INTERVENES MESSAGE

Communication across different professions is essential for bringing an idea to materialisation, and various ways of enhancing the quality of the dialogue have been studied in participatory design [5]. In such communication, it has been claimed that noise intervenes with the message, and this makes the message from the sender difficult for the receiver to understand [6]. Donald Schön thinks that design students need to recognise this and understand how to build a bridge between their own practice and the various receivers of their messages [1]. Studies in creative methods in design practice confirm that visualisation can be a powerful communication tool, and it is often used by artists and designers [7-9].

2.1 From concepts to physical solutions

In the aim to understand creativity and how concepts can be connected to physical solutions, it is beneficial to learn from conceptual artist Joseph Kosuth and one of his main works, 'One and three chairs', where the concept chair is exhibited through means of a real wooden chair, an image of a chair on the wall and a verbal definition of a chair on a piece of paper on the wall. This demonstrates playfulness about what a chair is; is it a concept or is it a physical product? Kosuth's play with concepts is also reflected in another work, ‘A Play – News From Kafka and a Quote’, described by Dr. Gerald Silk, Professor of Modern and Contemporary Art [10]. The work is a newspaper article titled ‘Americans are found “downright angry” at political powerlessness’, and this article is repeated on several pages, where each page is combined with citations from ‘Parables’ by Franz Kafka [11]. Silk explains how Kosuth’s art for the magazine Art Journal simultaneously can be read as both verbal and visual text. This combination of the verbal and the visual is a topic that is also relevant in creative processes in design and engineering collaborations. It also shows how conceptual art can use existing elements in society, such as a newspaper article or a chair, and how, through conceptual and physical interventions, everyday objects are transformed into art.

2.2 From representation to pragmatism

Another example of conceptual art is a work by the artist Serrano, who has been accused of being blasphemic. The artist put a crucifix in a glass container and then filled it with his own urine before depicting it in a photograph. The work was called ‘Piss Christ’ [12]. An intention from the artist was that it was actually his own urine, not coloured liquid, because the art should be authentic; it should not be a representation or only a symbol. It certainly created a lot of discussion, and demonstrations were organised against this work [12]. Merino’s reflection on the work was that ‘Euphemism has become established as a way of repressing ideas, and the meaning of things is becoming diluted. For this reason, beauty is not enough. Art should not be a pleasant, beautiful escape mechanism. It should not be a euphemism covering over the holes in society, but the light that makes us reflect upon that society. That is why art is and will always be uncomfortable for the system. Art must move closer to activism rather than to the purely aesthetic. There is no aesthetic without ethics.’ [12]. The example shows how conceptual art aims to create a critical discussion in the public space by the use of both aesthetics, and also engagement in society, where provocation, discussion and demonstrations also become a part of the art concept. As such, there is no strict border that limits the work to the physical object separate from the discussion and communication that it creates; both the artwork and the communication are part of the conceptual work. This view has also been promoted in studies about public art [13].

2.3 Communication about kinetic art constructions

This background demonstrates that communication across different professions is essential for bringing an idea to materialisation in practice and that there are various studies regarding enhancing the quality of the dialogue in art [7, 10, 12], participatory design [5] and engineering [1]. Despite these studies, a knowledge gap exists concerning a pedagogical concept of communication that can connect conceptual art, cross-disciplinary collaboration in design and engineering. Expanded knowledge of this can benefit collaboration in design and engineering. It is possible that design theory with design principles of concepts and quantitative structures [14] could be communicated to engineers in regard to complex and kinetic art constructions [15]. There is a need to know more about how such creative concepts are transformed into practice because knowledge about both pitfalls and potentials can transfer to other situations and contribute to multidisciplinary innovation [16]. The research question for the study, therefore, was how could design principles and quantitative structures be communicated to engineers concerning complex kinetic art constructions?

2.4 Method: Case study of the unique creative event

A suitable approach was a case study of a real project, where the research question were developed based on the experience and the emergence of the empirical data, as a retrospective stance [17]. With such a practice-based approach from research and enterprise, it was possible to document empirical data that could be analysed to inform design and engineering pedagogy [18]. Through a collaborative approach by the artist [5], a complex and technological public art sculpture had been developed cooperatively with other professionals, mainly engineers. Through the analysis, pedagogical [19], epistemological and ontological viewpoints were discussed. Such analyses were recommended by the art philosopher Juha Varto, who believes that there is an unused potential in artistic research to learn more from ‘the unique creative event’ [20]. The descriptive study is based on participatory observation and the prior understandings of the participant artist, and the intention is to aim for a fusion of horizons [21, 22] across professions.

3 FINDINGS: A KINETIC ART SCULPTURE

The case study presented in this article is a conceptual art project including a public sculpture funded by the municipality of Nesodden and Public Art Norway in connection with a new municipal building containing schools, libraries and municipal offices. The main concept behind the sculpture project was to use the airflow from two ventilation systems. To explain the concept for the engineering company, a simple three-dimensional model was produced to illustrate the different functions visualised in the study (Figure 1).

3.1 Part 1: 'Pulse' - a mock up of a conceptual artwork

The artwork was titled 'Pulse'. The title alludes to the artistic concept of enhancing the connection between the sculpture and the pulse of the house through the ventilation systems in the building. It was intended to be placed in an enclosed outdoor space, an atrium, so that it would be limited and not physically accessible to people. The sculpture was based on the draft from the two ventilation systems, which were dynamic and reflected the activity in the building. Many people in the building lead to more pressure in the building. The sculpture would respond to this and work according to the activity in the different parts of the house. It was a kinetic sculpture that was functional and operated by air from two separate ventilation systems. Physically, it consisted of two main parts (Figure 1). One was a vertical aluminium cylinder rotated by using the air from one of the ventilation systems. The second part was driven by the second ventilation facility to lift and pull up a 'hammer', which was jacked up until it reached a certain point, after which it would fall down and leave a mark on the cylinder. This mark would, in principle, not hit the same place twice and would, over time, change the cylinder's appearance and shape.

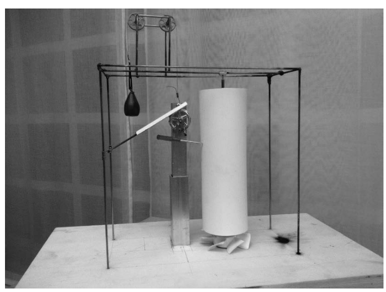

Figure 1. Step one 'Pulse': A mock-up of the public art sculpture in paper, steel and polypropylene; a hammer that leaves marks on a cylinder

The model was a visualisation on a fundamental level, and the intended meaning was to demonstrate different functions. The model was performed on a scale of about 1:10 and consisted of welded steel and other metals, plastics and paper. Its height was 25 cm. The design was simple and transparent, based on the intention that people should be able to read what happens between the house and sculpture. The model was intended as a description of the functions and not as solutions to them.

3.2 Part 2: An impossible solution

The model was presented for a big Norwegian engineering company, which in its advertising claims to specialise in leading 'ideas into a finished product'. The mock-up model was seen and analysed by people in the company, and the idea of the 'solution' in the model was discarded as an 'impossible principle'. In particular, there was one part where friction would occur, and thus it would not function in relation to the air pressure/flow from the building. Therefore, they started with a completely new concept for this part of the sculpture. Given this, two things happened. Firstly, the firm took more responsibility to solve this problem, and secondly, the artist was put off this part of the process because this was outside the artist's area of expertise.

In connection with the production of part one (the cylinder) and the supporting structure, no problems emerged; there was a good dialogue. This solution was close to the model's expression, and the process was conducted in full compliance with the artist. Dialogue with people with different competences was both necessary and desirable for this type of project, where the artist did not have the necessary competence. It also meant that through this partnership, unexpected solutions to specific problems could emerge. It was a situation where the artist gave up some of the control in respect for others' expertise and professionalism. At this stage, therefore, based on the model, one of the main parts was interpreted as an impossible solution.

Figure 2A and 2B: 2A: Step two 'Pulse' real-size installation on site; first version. It was a failure because the air from the ventilation system did not move the hammer. Figure 2B: Step three: 'Pulse' real-size installation on site; second version, including a frictionless bellows, and where all functions were safeguarded and resolved according to the original concept

Pictured above is the solution initiated by the artist and completed by the engineering company, as it appeared when it had been delivered in full scale onsite. The blue cylinder part in aluminium was as intended, while the other part was a solution that was complicated and expensive but not fully functional. It contained two chambers scheduled for pulling and lifting the 'hammer', intended to turn into the cylinder at different heights. When it turned out that it was impossible to get it to work as intended, new layers of new parts were gradually added to compensate for the lacking function. All this happened without success. It all took a very long time, and gradually recognition grew in the engineering company that it would not be possible to construct and produce the project as intended. The conclusion was that the artist took over the project again and involved new partners for further development.

3.3 Part 3: Conceptual consciousness in collaboration

The process moved back to its starting point. The dialogue with a new engineering firm from Denmark turned out differently. The artist experienced more mutual respect because the collaborative partner approached the problem in a different way. The firm employed more responsive communication. It was a more conceptually conscious company that showed a strong desire to communicate during the process. In addition, there was the failed experiment as an example. Discussions immediately started on a subordinate issue, a dialogue that happened in an informal setting. It was in a café, as opposed to the former dialogues, which all happened in more formal environments. Through conversations and drawings, a solution emerged. This was the approach that improved the failed main part of the sculpture. Based on the initial model, the artist and the second engineering company developed a frictionless bellows inside a form with a built-in control. Combined with pulleys and weights, it provided an optimal solution that could function and had very good sensitivity to minor fluctuations in airflow. The functional principles of this part were redefined in accordance with the overall art concepts and were manufactured successfully to work as intended.

The communication between the sender and recipient [6] emerged in a good way, where noise that disturbed the message was reduced based on mutual respect through participatory design methods [5] and by gradually and collaboratively establishing a common understanding of the problem that should be solved. Instead of starting off with a rejection, the collaborative approach headed for the core of the problem, and in this way a functional solution was found. The picture (Figure 3) shows the finished result, in which all functions were safeguarded and resolved according to the original concept.

4 DISCUSSION: VISUAL COMMUNICATION IN A KINETIC SCULPTURE PROJECT

In this case study, there was a need to connect examples from contemporary art [10, 12], collaborative approaches in design [5] and engineering [3] to fully understand the project. It was a connection of several research fields, which, according to Varto, is called imprinting—how a research study of a unique creative event needs to borrow concepts from other research fields to explain a process where the aim is to create an expanded understanding for the reader [20]. Such an epistemological perspective in this study is that there are a variety of knowledge fields to consider in a practical project. Varto further elaborated on the need to identify the view of man in practice, with an aim to position examples of education in an ontological perspective [20]. In this case study, a topic was how communication could happen with mutual respect and an expanded understanding of each other's competence in a collaboration process. The learning outcome for design students is to understand the need to encounter various different cultures with a worldview of knowing how to contribute to a dialogue with mutual attentiveness and respect. A further learning outcome for students is to have the general competence to find information from research fields with different traditions. The study shows how a real process in a real-life situation with real objects can lead to failure in the materialisation of a project. The practice showed how different disciplines can have different 'language games', as introduced by Wittgenstein [2], where prior understandings [21] and professional competence can make it hard to communicate in a productive way across professions [1].

4.1 The degree of abstraction versus the risk of misinterpretation

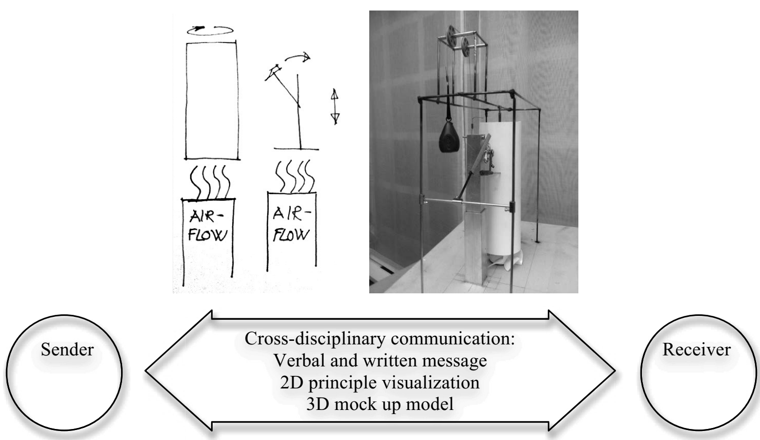

Figure 3. A pedagogical concept: Abstraction versus the Risk of Misinterpretation (ARM): A combination of a principle model + a physical mock-up model to be implemented in the communication process. The sketched drawing is on a principle level for the first stages of development

It would be only speculation to conclude that the second approach was better than the first because there was an unsuccessful attempt to take the final dialogue into account. Instead, the answer to the research question 'how could design principles and quantitative structures be communicated to engineers concerning complex and kinetic art constructions?' concerns a topic that emerged from the process: the degree of abstraction versus the risk of misinterpretation. In this case, the process documentation demonstrated how the artist underestimated how literally the recipient interpreted the visual representations. This may have been due to a mutual lack of understanding of each other's professional cultures [4] and each other's prior understandings [21]. In the first dialogue, the model was understood as a functional solution, although it was intended as a physical representation of a principle structure. By using the Tjalve method of principles and quantitative structures, one would be able to increase the abstraction level, and the visual representation would not hinder a more conceptual interpretation [14]. This could have been done, for example, in combination with the initial physical mock-up, as shown in the visualisation of the pedagogical concept Abstraction versus the Risk of

Misinterpretation (ARM) (Figure 4). The study shows that there was a need for extended understanding of the non-verbal communication that can happen through visual expressions. For designers, it is essential to be aware of these challenges in meeting other professionals. Students would benefit from being prepared for these kinds of situations in collaborative design practice by handling conceptual consciousness and how it is reflected in art, design and engineering. Product design students will in such cases benefit from being able to make conceptual visualisations as well as physical mock-ups.

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UNIVERSITY-INDUSTRY EXPERIENCES. CASE OF A UNIVERSITY-INDUSTRY-ADMINISTRATION AGREEMENT

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ABSTRACT
This article describes the author's experience in R&D projects developed in collaboration with industrial companies or the state administration ─agreements─ and their relation with university education. In the last sixteen years he has been the head researcher in nineteen agreements: sixteen with companies, one with the state administration and a medical institution, one with the administration and a company, and one with the administration. As can be seen, the author's collaborative preference lies with companies, usually in the form of small agreements with local SMEs which put an emphasis on the conceptual design of product engineering. The results of these collaborations are product designs and patents. These agreements are legal contracts between the company managers and the Rector of University. This article presents three examples of agreements. More specifically described is a University-Industry-Administration project, or "triple helix", to redesign Barcelona's rubbish containers for adaptation to wheelchair users.
From the educational point of view, the results of these projects led to an increase in participants' knowledge and practice, including the lecturer, who directly or indirectly transferred the knowledge gained to the classroom.

Keywords: University research, triple helix, education.

1 INTRODUCTION

The main tasks of a university lecturer are teaching and research. Teaching and research feed off each other and allow knowledge to be transferred and university faculty to keep abreast of developments in their fields. In order to apply research to engineering design, it is important to establish relationships with local production sectors. Hence, university teams work hand in hand with companies to make technological developments and obtain economic benefits in a win-win relationship, but without university's loss of independence. Faculty are assessed on the basis of their curriculum vitae, which outlines the three main areas of work, i.e. teaching experience; scientific and technological experience in R&D projects promoted by the administration or companies; and scientific and technological activities, especially scientific publications or works.
R&D project agreements are not only a way to improve university education, but also a source of income for the university and researchers. These agreements often involve the participation of final year or PhD students and/or, occasionally, technical staff.
Although the author is primarily involved with undergraduate education, he also teaches postgraduate and PhD courses and makes their management. Additionally, he has conducted research, especially in conceptual design, and participated in agreements with local companies.
This paper presents data, results and experiences gained from agreements between companies and academia, with a special mention to a University-Industry-Administration project.

2 DESCRIPTION OF AGREEMENTS

This section gives three examples of the above agreements: a project in collaboration with a medical institution approved by the state administration, several agreements with companies, and a University-Industry-Administration agreement.

2.1 Agreement with the state administration and a medical institution

A rowing bicycle for paraplegic users (figure 1) was designed within the framework a program of the state government [1]. A scholarship was obtained and collaboration with a medical institution for disabled people [2], some of whom took part in the project, was essential to conduct tests.

Figure 1. Prototype of rowing bicycle for disabled users. Source: National Geographic Spain (April 1999)

The project involved much bureaucracy, and although the prototype was commended by government representatives, a second scholarship requested to improve the prototype was denied. Nonetheless, a patent was made [3].

2.2 Agreements with companies

These agreements (twelve), were mostly small collaborations with local SMEs. They consisted in technical assessment and conceptual design. In one particular case, some parts of a cooking robot, including the casing, which was redesigned by a student of architecture (figure 2). The result was the improvement of the appearance of the device.

Figure 2. Left: Design of a casing (by Albert Lloveras). Right: Cooking robot (source: Pujadas Group)

2.3 Case of a University-Industry-Administration agreement

A University-Industry-Administration agreement consists in the collaboration between two institutions and a company to develop a project. This union, described by Etzkowitz [4], Etzkowitz and Leydesdorff [5] as “triple helix”, has advantages in some types of projects. The project here presented was aimed at making city garbage containers accessible for wheelchairs users. The management of these containers is the responsibility of Barcelona’s cleaning services whereas their supply is managed by private companies, as well as transport of urban waste to its final destination.

Each container is identified by a colour, i.e., brown for organic waste, blue for paper and cardboard, green for glass, yellow for plastic and metal packaging, and grey for general waste. Citizens carry these fractions in bags from their homes to nearby garbage containers. There are about 25,000 in the city.

Figure 3 shows some old containers in 2004. Grey containers (figure 3, left) were not accessible to wheelchairs users and, in general, to people who could not press the pedal to lift the lid of the container and put the rubbish bag inside. Moreover, the lid was heavy and closed too rapidly upon release of the pedal. The opening in blue and yellow containers (figure 3, right) was too high to be accessible to wheelchair users. Since at that time organic waste was not collected, there were no brown containers.

Figure 3. Left: Old container for general waste (grey) (own source). Right: Old containers for paper (blue), glass (green) and packaging (yellow) [6]

The initiative of this agreement came from the city’s cleaning services. They contacted a design team from the Universitat Politècnica de Catalunya and a garbage container manufacturer who was willing to participate in the project [7]. This company gave scholarships to two students who were preparing their final project, followed up on the project and built and tested the prototypes. The university team coordinated the project. For seven months, several design solutions were proposed at monthly meetings with the representative/s of the cleaning services and engineer/s of the company. The requirements of the project were that the new containers should have the same capacity and lateral size as existing containers to avoid the need for changing the collection trucks.

The pros and cons of all solutions were analyzed, and opinions about the designs were given by the engineer/s and representative/s of the cleaning service, as well as by disability organizations. Two alternative designs for the general waste (grey) container (figure 4) and two for the paper (blue) and packaging (yellow) containers (figure 5) were presented. Figure 4 shows the solutions for the general waste (grey) container, i.e. the lid of the container is raised by a lateral handlebar with an internal mechanism (left), or by a handle directly attached to the pedal (middle and right).

Figure 5 shows two designs of paper and packaging containers, i.e. one with two holes in the front of the container (left), and one with a mailbox-type opening at a height suitable for wheelchair users (middle and right).

Two of these initial designs were selected for prototype development. The container with the handlebar attached to the pedal (figure 4, middle and right) was chosen for general waste collection whereas the container with the mailbox-type opening (figure 5, middle and right) was chosen for paper and packaging collection.

The company protected the chosen solutions with two patents and made several prototypes that were placed in some streets for several months with satisfactory results.

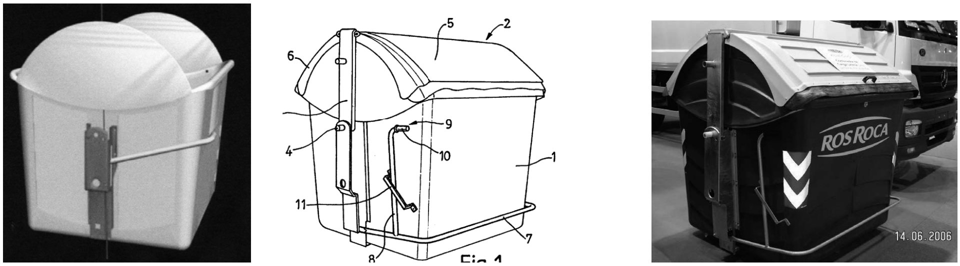

Figure 4: Grey container solutions and prototype. Left: Drawing with lateral handlebar (source: Bayod - Carreras). Middle: Alternative solution with lateral handlebar attached to pedal (drawing: Ros Roca). Right: Prototype in a trade fair (own source)

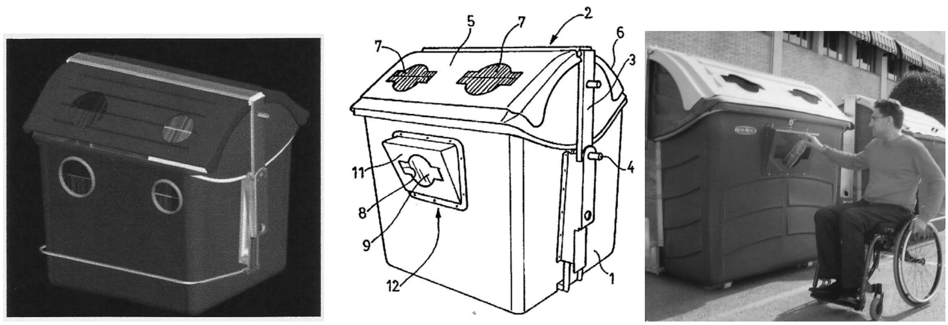

Figure 5: Blue and yellow container solutions and prototype. Left: Blue container with two extra openings in frontal panel (source: Bayod - Carreras). Middle: Alternative solution with "mailbox-type" opening (drawing: Ros Roca). Right: Prototype in a trade fair (own source)

Discussions about the design continued after the agreement had come to an end and some prototypes had been tested. Finally, the company decided to choose the other designs for industrial production (figure 6). The container with a lateral handlebar was selected for general waste collection (figure 4, left) whereas the container with lateral holes was chosen for paper, glass and packaging collection (figure 5, left).

Figure 6. New containers, from left to right: blue (paper), green (glass), yellow (packaging), two greys (general waste), and brown (organic). Diagonal Av. Barcelona (own source)

The maximum height of containers regarding wheelchair users allowed in ergonomics manuals is 1.4 m tall, which was left by openings or holes in the containers. The top holes were eliminated in the new design, which had new holes accessible to everybody. The new containers had symbols in relief for the blind and were placed throughout the city keeping the same order of colours. Subsequently, the company launched a final design of the external shape of containers (figure 6) [8], with engineering and ergonomics based on the university team's design. In the meantime, organic waste collection was initiated. The organic waste (brown) container was designed just as the waste (grey) container, but smaller in size.

3 RESULTS

The aim of the nineteen agreements was mainly to design or redesign products or part of products (twelve of them), sometimes only reaching the stage of conceptual design of product engineering and others the stage of detailed designs. Six were technical studies and one was a training course.

Among these agreements, sixteen were made with eleven different companies; three companies collaborated in two agreements and one in three. Most of the companies were local SMEs. In addition, one agreement was made with a design institution and another one with a state institution.

The sources of the agreements were diverse: One was expressly requested to a state institution, but the rest were welcome to be developed. Two companies came in touch with the Centre of Technological Transfer (CTT) of the Universitat Politècnica de Catalunya, who connected them with the university participants. Five agreements were made with them. An executive of a consulting company who was also with the teaching department proposed two agreements. Another agreement was signed through a university professor. Another one was born as a result of winning an award. Two published university patents also led to the signing of agreements with two companies. In one, a training program for a new R+D department in the company was developed from a postgraduate course [9], which consisted in the learning and practice of creativity techniques and innovation procedures. Two from a head of a company, and finally, four agreements were from students that were granted a scholarship and needed a research tutor.

These nineteen agreements lasted 122 months in total, with an average of 6.4 months per agreement and 1.2 agreements per year. Some periods were quite intensive but two periods of nearly 3 years went without agreements. The amount of time devoted by the author for each agreement is different: Twelve agreements required much dedication, two some dedication and five little dedication.

The direct participants in these 19 agreements were 44 (an average of 2.3 per agreement), although there were also occasional collaborators. They participated in agreements: 23 undergraduates, 8 PhD students, and 7 technical staff and others.

One of the most important agreements was the University-Industry-Administration project to redesign Barcelona's rubbish containers.

4 DISCUSSION AND CONCLUSIONS

One early experience of the author as the head of research was the university-medical institution-administration agreement (rowing bicycle). However, it involved much bureaucracy and financial aid was cut off after the building of the first functional prototype.

His preference was for agreements with industrial SMCs to develop conceptual engineering designs of products, so he ruled out organising projects within state programs. The advantages of this option are more agile relationships, less bureaucracy, close contact with the company's technical staff, and view of current business problems and world context. The disadvantages are that the projects are small and have low budgets.

Some specific technical needs of companies can be solved by academia. Therefore, it seems appropriate to jointly develop conceptual designs from SMCs, and in this context, the knowledge of faculty members and good students is often required.

Experience shows the possibility of closer collaboration between the engineering school and industrial companies. However, more must be known about the culture and needs of the two parties to row in the same direction in a win-win collaboration. Companies need to understand professors' curriculum vitae needs and be aware that granted students must be promptly paid.

The number of students that collaborated in these university-company agreements is very low. Students and lecturers come in contact with the company's reality and finest commercial criteria. They also gain interest in the final product and feel the pressure of time. These points of view are hard to find in the university and are complementary to student training. The above agreements led to an increase in participants' knowledge and practice and also provided lecturers with a point of reality, an experience which was directly or indirectly transferred to the classroom. In this context, all undergraduate students must undertake a traineeship in a company.

The University can help companies, especially SMEs, in the initial phase of an innovation, because at university time to think can be taken whereas in companies decisions often have to be made on the spot. Moreover, students are trained in technical skills and creativity techniques, know patent databases and design processes, have a fresh vision of the current product, etc. However, R&D activities are both a risk and the future of companies. University-company agreements are generally an investment for the future that keeps the industrial network.

The joint efforts of government-university-company (triple helix) were very useful as the views of all parties involved in the project were considered to design the garbage containers. This resulted in increased safety of the designs. All aspects were checked step by step; otherwise, some would have been only speculations. At this respect, for example were consulted organisations of disabled in wheelchair or of blind persons for to check the new design. It was a very interesting project. Moreover, in each course a class was devoted to a description of and discussion about the process followed to complete the project, including the key points of the design, how it came to the proposed designs and a whole analysis. Students showed much interest and asked several questions.

ACKNOWLEDGEMENTS

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INTEREST IN THE COMMERCIAL? USING COMMERCIAL DESIGN PROJECTS IN PEDAGOGY

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ABSTRACT
This paper considers the issues surrounding the use of live commercial design research projects as teaching material for Product Design students. The premise for the paper is based around the Design Unit, a design and research group at De Montfort University in Leicester, staffed by academics who are also involved in lecturing product design students. It highlights an observation that students may not become highly engaged when presented with assignments based on 'real life' design projects that have previously been completed by Design Unit staff.
It could be argued that such projects are simply too big, the detail can seem esoteric and feel irrelevant to the fledgling designer. In addition, the commercial constraints of the real world project could, at times, impose inappropriate restrictions on student designers.
As a lecturer used to dealing with industry experts and then being expected to present to design students on a project within a new industry sector, it could be quite easy to become complacent with regards to the student's prior knowledge. The aims of this paper are to explore what key areas can be extracted from commercial projects to make the best use of them as educational material. It will aim to suggest tools that could be used to present the material in an effective way and how this could better engage the student to help them understand the validity of the proposed design project or teaching aid.

Keywords: Case studies, live projects, commercial design projects.

1 INTRODUCTION – THE DESIGN UNIT

The Design Unit is a multi disciplinary research group at De Montfort University staffed by a number of academics carrying out live product design projects with commercial clients.
As a result of their work, the group generates research outcomes for the university. Their activities also provide a strong link to industry with SMEs /large blue chip companies as clients but also with a raft of commercial suppliers and specialists.
The academics within the group are also involved in lecturing to Product Design students. To this end, there is a wealth of useful knowledge within the group and a broad range of potential teaching material to choose from. As the scope of projects undertaken by the group has become more diverse, it has become more difficult to tailor projects/ aspects of projects to be used in pedagogy.
The issue explored by this paper is how does the research generated by the Design Unit and similar design research groups at other universities filter down to become useful teaching material? This paper aims to examine, what should be extracted from a typical live design project, how it should be presented and by whom to give students a relevant view of empirical product design.

2 THE DESIRED LEARNING OUTCOMES FROM PRESENTING 'LIVE PROJECTS'

Design is a skill based profession, Dym and Little 2008 state: *'like riding a bicycle or throwing a ball, like drawing, painting and dancing, it often seems easier to say to a student "watch what I'm doing and then try to do the same thing yourself!" there is a studio aspect to try and teach any of these activities, an element of learning by doing' [1].* The learning through doing approach, demands that, the design lecturer must refrain from simply presenting pertinent facts from a live project which could promote the student to engage in the 'skim' learning of facts or 'surface learning'. Instead the teacher must encourage and inspire the student to undertake further proactive study/design practice, thus encouraging 'deep learning'[2]

2.1 Creating the ‘need’ for knowledge

The journeyman design lecturer must also aim to develop an intrinsic motivation within the student to learn about the subject area in question. When presented with something new, it could be observed that unless students are aware of the value of the subject matter, they are apathetic towards it. Once students understand that what they are being presented with has validity, they are more likely to be engaged and to undertake deep learning. This could be seen as self perpetuating in that once the ‘need’ to learn about a subject is understood, the hunger for knowledge increases. This is illustrated in the diagram below (Faulconbridge 2008) [3].

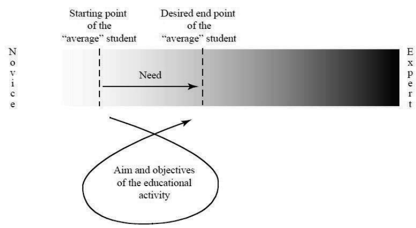

Figure 1. An illustration showing how the need for knowledge increases as knowledge is learnt Faulconbridge 2008 [3]

3 DESIGN UNIT - A PROJECT CASE STUDY

The following case study outlines a project undertaken by the Design Unit. Whilst a straight forward project in terms of technologies used, it has been chosen to demonstrate a sample of areas that ‘could’ be extracted to be used as teaching material:

Company SP produce a range of pneumatic pressure redistribution mattresses for the prevention of pressure ulcers in hospital patients who are confined to a bed. The inflation/deflation of the mattress is controlled from a central electronic control unit. As well as housing all of the pneumatic pumps/valves, this control unit also acts as the user interface for the product.

Another factor of the product is the quick release ‘CPR valve’. This allows for the air within the mattress to be quickly expelled in the event of the patient requiring CPR.

Company SP approached the Design Unit at De Montfort University to redesign their current range of mattress control units and CPR valves.

Figure 2(a) Existing Control unit 1

Figure 2(b) Existing CPR valve in machined aluminium

Figure 2(c) Existing Control unit 2

A ‘conventional’ design process was followed for this project. The results are shown below:

Figure 3(a)

Figure 3(b)

Figure 3(c)

Figure 3(a) & (b) Two iterations of the finished product *(the new CPR Valve shown with the red button on the left of each product)* 3.2c shows a split line that presented the designers with a challenge

The project presented the Designers with several unforeseen challenges during the design process:
Figure 3(c) shows a split line around the CPR valve exit port that was particularly taxing to ensure simple ‘open-shut’ tooling, negating the need for sliding cores.
Other challenges included designing a quick release air valve that could be used repeatedly without air leakage, creating a means of dampening vibrations from the air compressor that was to be used in the product, devising a cost effective way of mounting the control units to almost any hospital bed, creating an enclosure that was modular and could be used in for a wide range of model configurations, complying with relevant standards, styling plus many more.
A close working relationship with the MD of the company was critical; relationships were also developed with the company’s electronics contractor and their internal specialists/ engineers.
To summarise, this project has many of the factors that the fledgling engineering/product designer can expect to encounter when embarking on their career (particularly if working with SMEs).

4 IDENTIFYING PROJECT AREAS FOR TEACHING FROM THE CASE STUDY

The following project areas have been selected to discuss their suitability as teaching material

Table 1. Knowledge factors identified from ‘Commercial project’ for potential teaching material

Identified area of project knowledge	Suggested Use as teaching material
Difficult split line between case halves	This could be used as an aid to teach students about injection moulded component design and the avoidance of undercuts (CAD exercise?)
Designing a strong mounting system in plastic for mounting to hospital beds	This could be used to demonstrate how to design structurally sound profiles in plastic
Dampening the vibrations of the air compressor	This could be used as a practical example to introduce the student to NVH analysis
Working with other specialists and working to a project plan	This could be used as a teaching aid in design management
Designing a modular/common enclosure and chassis to be used by a range of models	Modular design is a key feature of many products; this project could be used as an example.

It could be argued that any of the above factors could be elaborated upon to create teaching material. Each factor was experienced by the practising designers working at the Design Unit. This should give credence to these factors being empirical and suitable for use in teaching. However it would be all too easy for the design practitioner who spends more time engaged in design with specialists and their peers than lecturing, to overlook the inexperience of students.
Any of these factors presented in isolation, be it in lecture form or as a case study for example would most probably be seen as esoteric by a student. At best the student would be encouraged to surface learn and perhaps retain some facts for future reference as opposed to ‘deep learn’. One of the elements Gibbs (1992) discusses when talking about fostering a deep approach is a well structured knowledge base. He states ‘without existing concepts it is impossible to make sense of new concepts. ‘It is vital that students existing knowledge and experience are brought to bear in learning’[2].
Is the knowledge discussed above therefore of little use unless it, by chance happens to coincide with a particular design project being undertaken by the students being taught?
The knowledge outlined in table 4.1 could be described as ‘professional knowledge’. Leinhart et al (1995) [4] actually form a distinction between ‘Professional knowledge’ and ‘University Knowledge’ Biggs 1998 explores this further summarising these concepts as ***‘professional knowledge****: procedural, specific and pragmatic dealing with executing, applying and making priorities and* ***University knowledge****: declarative, abstract and conceptual it deals with labelling, differentiating, elaborating and justifying’*. He goes on to discuss that university teaching for the professions is often declarative with a skills component taught separately as procedural knowledge. It is then left to the student to integrate the two domains [5]
In theory, a simplified version of Company SP’s case study could be an ideal tool in demonstrating how the gap between university knowledge and professional knowledge is bridged and how the

skills/knowledge the students are learning are applied in industry. It seems the challenge is aligning such a case study with the existing curriculum and making it a tool to aid deep learning.

5 INCLUDING A LIVE PROJECT IN THE CURRICULUM

When thinking about how to present this 'live' project material to undergraduate students we must consider the knowledge and skills we are trying to equip them with and the way in which they may learn. Kolb (1984) puts forward his now well known cycle of experimental learning shown in Figure 4[6].

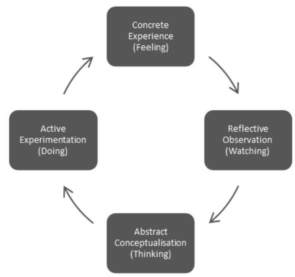

Figure 4. Kolb Cycle of Experimental Learning [6]

This is a model particularly suited to the product designer/design engineering student as it combines both the hands on and theoretical aspects of study. It is also conducive to the pursuit of deep learning.

Ideally, the live project should immerse the student in one of the four areas Kolb identifies, to begin the cycle. Even if this could be achieved we are still left with the question of where the live project fits in to the curriculum.

Biggs (1999) discusses his principle of 'constructive alignment' [5], in regards to consistency in the curriculum. He alludes to the course/module learning objectives, the teaching activities and the assessment criteria, all being aligned.

In presenting live projects to students, it could be argued that the material used and how it is taught should really be a pre planned exercise that is signed off by other teaching staff/module leaders and course leader involved in planning the curriculum. As appealing as it may seem to have a design practitioner to carry out an 'ad hoc' lecture on some recent work they have done, unless this is fully aligned to the course, then deep learning is unlikely to be encouraged.

At DMU where both BA and BSc product Design Courses are run, the main design project modules are aligned and supported by academic modules that 'feed in' to the main design projects throughout the course of the semester. For example, a main design project for a particular semester could be supported by modules in CAD, Materials and Manufacturing, Design process and hand drawing. The skills/knowledge learnt in these modules should come together to be used in the main design project itself. It has been observed that students can be slow to see the relevance of the supporting modules when undertaking their design projects. This integrates with the student combining declarative and procedural knowledge.

It could be stated that there is a clear benefit of using the experiences of a commercial project as teaching material in bringing together these modules and showing the student the 'real world' relevance of what they are learning in their studies.

6 REVERSE ENGINEERING PROJECTS AS A WAY IN TO THE CURRICULUM

Many product design/engineering design courses now carry out a project in which a product is procured, dismantled and its design/manufacture retrospectively analysed to try and assess why the artefact was designed/manufactured in a certain way. Sheppard (1992) refers to the practice as 'mechanical dissection' [7]

If we use the product(s) from the case study of company SP in section 3, maybe this could be the ideal route in to the curriculum? The product certainly has enough depth for this type of project and it could be that many of the areas of knowledge identified in table 4.1 would proactively be struck upon by the student. For example when talking about the 'dampening of the vibrations from the air compressor', the student would see upon opening up the product that the air compressor is sat upon special dampening mountings. They would then perhaps start to enquire why?

Also, the tutor could ask the question *'Can you see any parts of the injection moulded case that would have been difficult to design'?* This would hopefully lead to the student applying their base knowledge and perhaps identifying the area of the difficult split line (identified in table 4.1) themselves. If not, the tutor would be on hand to give the answer and the student would have a good grasp of the context of the problem after already trying to identify it for themselves.

In both cases, the student's 'need' for knowledge should be self-generated (as discussed in section 2) whilst they carry out the disassembly. The student will also have hopefully started their journey on Kolb's experimental cycle of knowledge. [6] Historically, it could be observed that the drawback of this kind of project is that it relies on the tutor having a deep enough understanding of the product being dissected to guide the student. If a piece of technology is purchased and upon dissection it appears the teacher is technically out of their depth, then the exercise quickly loses some credibility.

One of the major benefits of a product being dissected that was designed by the tutor is that the tutor will know the product intimately. They will be able to discuss some of the problems they overcame in context and be able to answer in depth questions about the nature of the materials used, the technologies employed, the physical structure, colour, texture and so on.

Another benefit is that the designer may well have a close relationship with the manufacturer(s) of the product (this is certainly true of the case study in section 3). In which case they may be able to arrange student visits to an injection moulder a tool maker or an assembly line for example.

The designer should also have examples of how the product developed through the design process, i.e. sketches, models, technical drawings, first off mouldings with imperfections etc. This evidence could all be used in subsequent lectures to tie together the design process and give students an empirical example of the skills that they themselves are learning but perhaps don't realise when to apply them.

Asa Harvard [8] talks about the importance of the artefact itself being used as an educational tool in a *'knowledge culture centred on producing artefacts'* This approach is certainly true of the reverse engineering project, as the artefact being dismantled contains or has undergone many of the processes being taught on the course.

These projects should also give credence to the guest lecturers/academics who have designed the artefacts being dissected. It could be argued that in the era of higher fee paying where students are 'calling the tune' [9], the confirmation of quality in lecturing staff (practising what they preach) is more important than ever.

7 LIVE PROJECTS: GUEST LECTURER OR A FAMILIAR FACE?

Biggs (1999) discusses the academic as being primarily concerned with keeping up with their chosen area of research first followed by their teaching practice second [5]. It could be observed that many students wouldn't be aware of this and simply see their tutors as just that, i.e. tutors simply delivering a syllabus dictated by the university. It could be assumed therefore that when faced with the prospect of a guest lecture on the subject of a 'live project' delivered by somebody in industry, students would find this more motivational than the content delivered by their normal university lecturer. Rather surprisingly, when this question was posed to the final year BSc Product Design course students at DMU, the results were to the contrary:

Question: Would you hold the 'live project' lecture content delivered by a practising designer in industry in higher regard than the lecture content delivered by your usual DMU academic? The possible answers were as follows:

1. Yes, I hold the practising designer content in higher regard
2. No, I hold the content delivered by my normal DMU academic in higher regard,
3. No difference, the content of both is held in equal regard

90% of the students answered with option 3, the remaining 10% option 2. However when asked a similar question about the appeal of the lecture, the results were very different

Question: Would you make a special effort to ensure that you attended a lecture given by a visiting practising designer to discuss a 'Commercial project' over and above the effort you would make to attend a normal lecture given by DMU staff? The possible answers were as follows:

1. Yes, I would make a special effort for the visiting lecturer,
2. No, I wouldn't make any special effort
3. No difference

In this instance, the students answered unanimously 100% for option 1. These results are interesting and warrant further research. If nothing else it affirms the saying 'Familiarity breeds contempt!' The reason for asking this question was to ascertain if the commercial project material held any more weight if presented by a guest lecturer from industry/ a research group member who was involved with the project/product in question rather than the normal lecturer.

The Design Unit staff (and staff of similar research groups affiliated to design courses) could be seen as guest lecturers but they have the benefit of being close to full time teaching staff and course leaders. This means they are in a position to have their commercial work scrutinised by colleagues involved with the course and are thus better suited to align it with the curriculum.

8 DISCUSSION AND CONCLUSIONS

Whilst live commercial projects from industry may seem like an attractive proposition to aid teaching, there are many factors to consider when aligning them with the curriculum, such as obtaining 'buy in' from others involved with the course to ensure the material being taught fits in with the established curriculum, learning outcomes and assessment criteria. Also, the material must be presented at a suitable time when the students have enough base knowledge to take on board what is being discussed and to be inspired by it.

The reverse engineering projects are only one mechanism for presenting live commercial work to students. If up to date commercial project factors could be injected in to the curriculum at the front end (i.e. planning stage), then the material could be delivered in a very controlled way that is beneficial to constructive alignment. For example if there was a constant feedback loop between the research group and the heads of course who plan the curriculum, then they would know what content is available from the commercial projects currently being undertaken. The academics of the research group could then perhaps tailor their work to suit teaching material (without compromising the project) based on requests from the course heads who could be looking for a particular 'real world' angle on a given design assignment. In the first instance, the course material presented by the Design Unit could simply be in the form of a simple case study saved in PDF format, and stored in a library that is available for all parties to see (including the students). This would allow the live project material to be woven in to the curriculum at the front end as the course head deems fit, encouraging conceptual alignment as discussed in section 5.

This paper has explored how the 'Commercial project' can be interjected in to a design course. It could be said that any sporadic contact with professional designers and their live projects is a good thing if these extra circular meetings are not subject to academic study or assessment (i.e. do not have the effect of 'rocking the design course boat'). Such meetings can be invaluable to help students in knowing where to turn upon graduating and to aid confidence when embarking on their careers. They should also help in letting students experience the realistic tight deadlines and the level of detail that is expected of the designer working on a Live Commercial Project.

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PRINCIPLES GUIDING TEAMS IN NEW PRODUCT DEVELOPMENT PROJECTS

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ABSTRACT
This work describes the concept of establishing principles for teams in new product development projects. Principles provide guidance for teams and support them in decision making. They turn behavioural patterns of teams, that cover important aspects of collaboration, management as well as design-specific aspects, from an implicit to an explicit level and allow the team to develop a common understanding. Principles are formulated to invite for action with proactive phrasing and visualization of each key message. Aiming to let principle evolve into shared models for a team, we propose a sequence of steps from learning about principles for the first time to following a team-individual set of principles and taking consequential measures. To elucidate we introduce and illustrate a dozen principles. This exemplary set was presented to student teams and their coaches at the beginning of a nine month course for undergraduate students. In this preliminary and explorative study, the feedback of students and their coaches shows that the concept of principles was well understood by both groups and that they were stimulated to reflect upon them. The feedbacks also indicated, that the participants struggled to come up with new principles that differ from the provided examples. In the future, more thorough investigations shall be conducted into the usage of principles over the full duration of similar projects.

Keywords: Principles, new product development, design teams, shared mental models.

1 INTRODUCTION

Teams play an important role in product development, especially in the context of new product development (NPD) projects [1]. The daily work of teams in NPD projects is commonly supported and structured by processes (e.g. stage gate process) or methods (e.g. quality function deployment). A range of processes and methods has been widely established in teaching, research and industry practice. They help to deal with several kinds of challenges and offer approaches for situations with certain boundary conditions. However, particularly NPD projects are characterized by high uncertainty [2], nonlinear processes [3] as well as the uniqueness of each project [4], which means for some emerging problems no matching method or process can be found. There is not enough guidance and support on a general level, independent from fixed boundary conditions and applicable throughout the whole project.

For teams in NPD projects, we propose the introduction of principles, which should provide compass-like guidance on a higher degree of abstraction than processes and methods. Principles describe how to work together in the design team and how to approach design problems. The idea of principles for teams is to make an implicit working philosophy explicit, which is central for a common understanding on how to proceed and how to make decisions when facing challenges.

In the following, the general concept of a common mindset and shared mental model (SMM) is explained in relation to principles. Then a model for principles in teams is introduced and 12 principles are exemplified. Finally the preliminary feedback of students and coaches from an initial study are described.

2 FUNDAMENTALS

The idea, that a designer's mindset strongly influences the way he acts, is supported by the work of Andreasen. He stated that "the appropriateness of the user's mindset seems to be a very strong precondition for the proper application of methods." [5]. Furthermore in this context Person et al. pointed out, that "a proper mindset positively influences the designer's ability to use a method, as it allows him or her to more effectively address the problem or challenge at hand when designing." [6]. Whereas the mentioned authors refer to the connection between a mindset and a method, the principles introduced in this paper are intended to function on a more general level. Principles provide an orientation for decisions to be made in the design process and hence steer the choice of actions.

In contrast to the previous mentioned authors, who discuss on an individual level, the principles aim to support the designers on a team level. The explicit definition of a working philosophy with its textual and visual description allows the team to create a common understanding on how to proceed in the design process. This common understanding can be seen as a SMM within the design team. Cannon-Bowers et al. define SMMs as "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their behaviour to demands of the task and other team members" [7]. Especially in NPD projects, which are characterized by less routine procedures, SMMs are relevant to work effectively. Thereby SMMs can guide the behaviour of teams when dealing with new situations [8]. In their work about cognitive processes in design teams, Bierhals et al. found that the existence on SMMs of small groups (subgroups) are positively related to team performance [9]. Principles can help to create a SMM, which has an impact on the decisions the designers make.

One example of the explicit use of a concept similar to principles is the d.mindsets, developed by the d.school in Stanford. The d.mindsets consists of seven items that communicate relevant mindsets in fuzzy front end projects to the students (e.g. bias towards action) [10]. However, the question how to introduce and implement those mindsets to design teams and what effect their application has on them, has not yet been discussed.

3 SUGGESTED MODEL FOR PRINCIPLES IN TEAMS

This section is subdivided in three parts. First, the characteristics regarding the formulation and composition of the principles are explained. Second, the way principles are intended to be used are described and, third, a basic set of 12 principles is introduced.

3.1 Characteristics of principles

The visual and textual structure of the principles is intended to be catchy and easy to remember. Therefore they are composed of three elements: First, they have a short head-title of maximal four words (e.g.: *redesign your tools*). Second, they have a lead title, which describes the principle in more detail (e.g.: *challenge and adjust your working environment*). Both, head and lead are phrased in a proactive way, so that they invite for action. Third, a drawn image of an easily memorable scene gives a visual representation of the lead.

3.2 Usage of principles

We propose the following sequence for establishing the idea of principles in student teams: (1) Introduce the concept of working with principles and explain the 12 exemplary principles, which were provided as basis (see Figure 1). This helps teams to understand the way principles work since the idea of using principles is not familiar to them. (2) Encourage the teams to create additional principles at this point in time or later in the project. (3) Let the teams choose the principles they want to apply in their team and position them visible in the project room. (4) Let them determine how they use those principles and in which manner they will affect their design process. The individual implementation of resulting measures is an important aspect and a continuous ongoing process, as new situations will lead to new ways of implementing a principle.

3.3 Basic set of principles

To provide a basic set which should help to understand the general idea and to stimulate teams to develop their own principles, 12 exemplary principles have been formulated by the authors (see Figure 1). They address elements of project management, team collaboration as well as design specific elements. In the following the 12 principles are introduced by presenting for each principle the respective head and lead text, as well as a short description of its intended meaning. We aim to give the reader an idea about the formulation and variety of principles, but do not claim to have verified these specific principles in detail.

ITERATE FOR EVOLUTION - fail and learn from it
This principle highlights the relevance of iteration cycles. Iteration is seen as continuous repetition of synthesis and analysis. At the end of the analysis a validated learning step [11] (prototype, test, interview, calculation, etc.) is performed, before moving on with the next synthesis. Failing is explicitly allowed.
BREATHE IN BREATHE OUT - alternate divergent and convergent activities
The distinction and the alternation between divergent and convergent phases are important, because each of these two thinking and working styles require particular actions and attitudes. Especially in teams the awareness of the actual phase is essential in order to adapt ones behaviour e.g.: don't judge in the process of idea generation.
DOCUMENT AS YOU GO - write and sketch knowledge while developing it
Continuous documentation in the dynamic environment of a NPD project is highly relevant. On the one hand the whole team needs to have access to input created by one team member as fast as possible, because every work step is building upon these results. On the other hand documentation forces to think about a coherent red thread and supports validated learning.
FOCUS ON THE USER - understand the users' needs and react to them
Every product has one or more user groups. To find the user groups, to isolate their needs and to test the product ideas by confronting them and recording their reaction is relevant along the whole process. User reactions are also a good basis for validated learning.
CREATE ENERGY - establish rituals and emotionalize your work
Motivation and trust are important in NPD teams, as the team members are working closely together and depending on each other. The challenge of creating something new and the necessity of exchanging information continuously make the atmosphere in the team an essential success factor.
MINIMIZE DISTANCES - create physical closeness of people and resources
Short distances between team members as well as to relevant physical equipment, but also to the users enables to work in short iteration cycles. The strong negative correlation between the frequency of communication and the physical distance between colleagues [12] is often underestimated.
GET PHYSICAL AND TEST - build it to validate your thoughts
Physical representations of the ideas help to communicate, to understand, to analyze thoughts as well as to provide inspiration for further ideas. Especially in interdisciplinary teams prototypes help to create a shared understanding of an idea.
LEARN NEW SKILLS - be curious about what others do and how they do it
NPD teams are dealing by definition with the challenge to create a novel and valuable product. The curiosity regarding new skills, new approaches or new knowledge creates new perspectives on a problem or an idea. This can lead to new thinking styles and new product ideas.
GO RADICAL - be brave and go against common patterns
This principle aims to create an atmosphere, which allows to think about radical ideas and to push disruptive solutions. For reaching the limit on what is feasible, first going to utopia and coming back to the limit can be more helpful than starting at a current solution and improving from this basis.
REDESIGN YOUR TOOLS - adjust your working environment
Tool, methods and also the physical environment like the office space often don't fit to the individual problems that need to be solved in a NPD project. Hence this principle empowers not only to work on the problem but also on the toolset to solve the problem.
VISUALIZE TO CONVINCE - show me don't tell me
A picture is worth more than a thousand words. Visual representations are essential to convince others and even oneself of content. Only if team members really have the same understanding of an idea, they are able to give valuable feedback and make good decisions.

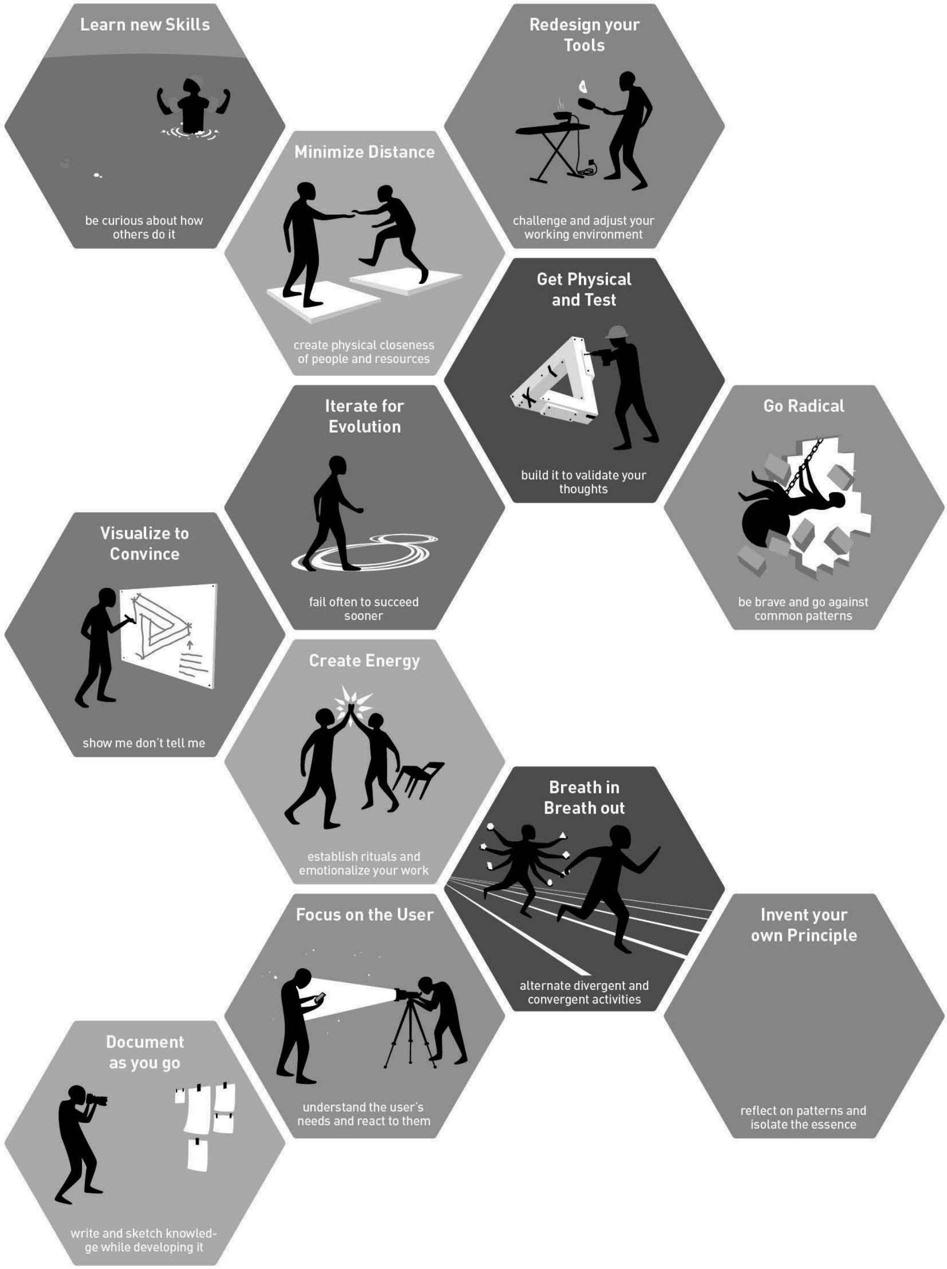

Figure 1. Principles for teams in NPD projects (12 examples)

INVENT YOUR OWN PRINCIPLE - reflect on patterns and isolate the essence

The prior described principles are not a complete set. Each team should set up their own composition and shape their own principles whether they are motivated by a value (e.g. sustainability) or as a reflection/answer to a behaviour or problem in their team.

4 INITIAL REFLECTION OF PRINCIPLES IN STUDENT PROJECTS

In a preliminary and explorative study the idea of using principles, in particular the 12 exemplary principles, were introduced to undergraduate students from mechanical engineering, electrical engineering and industrial design in Zurich, Switzerland. At the beginning of a nine-month project based course the students taking that course as well as their coaches were confronted with the principles. The aim of this investigation was to evaluate on whether the way the principles are composed (head, lead, picture) is understandable and how students would generally react to it.

After the first three days of intensive teamwork the 12 exemplary principles were presented to the students of the six project teams (39 students) by handing them out a printed version. They were asked how they would implement them in their actual project and if they already have ideas for own principles. Their notes showed that they understood how a principle basically works. For in average 84% of the principles they collected meaningful ideas on how they want to implement them into their projects. For example one team added “implement a timeline with milestones in the project room” and “create a promotion video to impress sponsors” to the principle *visualize to convince*. No team managed to formulate their own principles at this point of time.

The seven coaches who either performed the same course one year before or gained other experiences in similar projects were asked to reflect on the principles based on their former undertaken projects. The coaches’ notes were more detailed, showed less focus on the implementation of the principles and included more reflections regarding the evaluation of the principle in general. As shown in Figure 2 their answers were assigned to five categories, classifying their level of agreement to the principles. The principle *visualize to convince*, *breathe in breathe out* and *learn new skills* are strongly supported by the coaches. Surprisingly four answers pointed out that the principle *minimize distance* was very important for their communication, even though communication is not mentioned in the description of the principle itself. The two principles *iterate for evolution* and *go radical* were hardly discussed in the reflections. Iterations were often seen as time consuming and the question was raised how many iterations are possible within the course. *Go radical* was generally supported but five coaches mentioned that it should be limited to some phases or that it can be hard to communicate radical ideas to the stakeholders. Furthermore they had difficulties to reflect on *invent your own principle*.

The feedback by the students and the coaches showed that the structure how principles are set up is understandable and stimulates to reflect upon them. The student teams defined methods, tools or rituals to implement the principles in their projects. The coaches’ feedback showed that not each of the 12 principles are suitable for all project teams. This confirmed the assumption that each team needs to define its own set of principles to work with, consisting of given and self-created principles. However, the reflection also showed that the process of defining own principles in a Bachelor course is difficult for the students and must be supported by the academic staff. In further studies the influence and usability of principles have to be investigated over the full duration of similar projects.

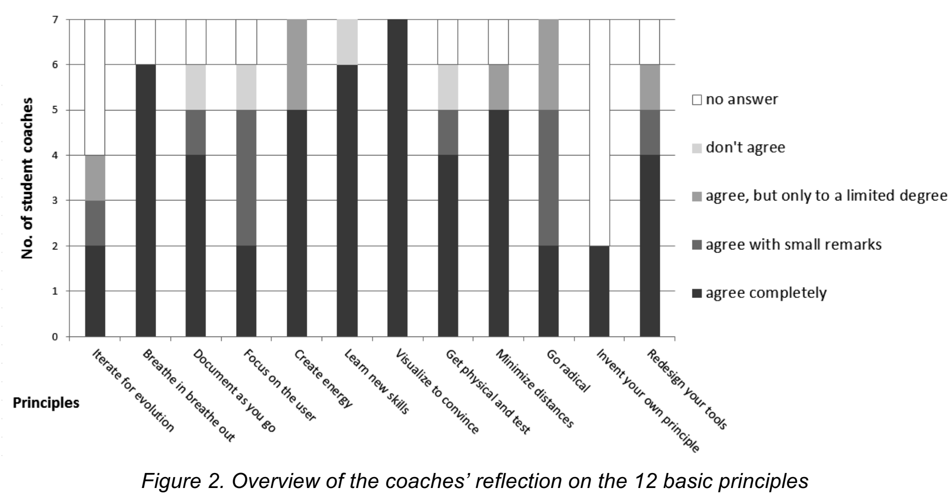

Figure 2. Overview of the coaches’ reflection on the 12 basic principles

5 CONCLUSION

This paper describes the idea of establishing principles for teams in NPD projects. Next to processes and methods principles can be an additional element to support and guide development teams. Principles make the working philosophy of a team explicit and thereby allow the team members to create a common understanding on how to proceed during the design process. They are phrased in a proactive way and are composed by the three elements: head, lead and image.

12 exemplary principles, which cover important aspects of project management, team collaboration as well as design specific elements are introduced. In a preliminary and explorative study, this set of principles was tested with undergraduate student teams and their coaches in a project-based course. The feedback of the students and coaches shows, that the structure how principles are set up is understandable and stimulates to reflect upon them. Furthermore they trigger a discussion about the design process and the prioritization of actions. Further experiments over the whole duration of projects has to be conducted in the future, focusing on implementation strategies and effects on team performance.

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WHAT WE LEARN FROM EXPERTS ABOUT ENQUIRY WHEN WE ENGAGE IN PROBLEM SOLVING

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ABSTRACT
This paper outlines a small-scale design-based research project in progress that attempts (a) to understand the use of enquiry during the early phases of the design process from an extended cognition perspective and (b) to synthesise such enquiry behaviour with broad types of problems. The is to draw implications for engineering education curriculum design in general, and for professional development of mining engineering at the University of Pretoria in particular. The first phase of the project entails defining a suitable theoretical framework encompassing design disciplines and levels of expertise to examine and develop design behaviour. Extended cognition, approached as an information-processing system, serves as a theoretical framework. The second phase, informing the third and dominant phase discussed in this paper, comprised empirical protocol studies on expert teams from three diverse domains, namely architecture, mechanical engineering and industrial design. The methodology and results were published elsewhere and are not part of this paper. The third phase, involves the beginning of a process of mapping extended enquiry onto extended cognition and problem-solving models accepted in both engineering industry and educational contexts. Preliminary recommendations are proposed integratively for the implementation phase of the project.

Keywords: Engineering education, design cognition, enquiry, problem solving, workplace.

1 INTRODUCTION

One of the central goals of engineering education for many lecturers is to promote engineering enquiry and problem solving in students [1]. Here, enquiry is seen as the search and discovery process within the problem and solution space of the early phases of the design process experienced internally and externally by engineers. This paper aims to address some of the educational needs identified by the mining industry by reporting on the University of Pretoria's (UP) effort to attend to third-year mining engineering students preparing for their fourth-year internship. Industry indicates that, in mining engineering in particular, there seems to be an urgent need for universities to support the long journey of novices, estimated to last ten years from graduation [2:944], before the industry deems them ready for appointment to their first substantive managerial or mining project design positions [3]. The real mining environment awaiting a newly qualified mining engineer is ridden with constant physical, hence non-routine context-bound, problems related to ensuring safety, ventilation, rock engineering, mine planning, mineral resource evaluation, and mineral asset valuation [2:937, 3]. However, research indicates that engineers experience more unexpected, non-engineering problems in the workplace than the typical engineering problems they were trained to solve at university [1]. The constraints engineers experience in the workplace are often not related to engineering [1]. This requires the connection between domain specific knowledge and externally observed information emerging from the physical environment. The general approach of tertiary institutions offering engineering degrees is to engage students in two years of content and scientifically driven tasks related to fields including mathematics, chemistry, geo-sciences and physics. In accordance with the convention in engineering courses over the past six decades, the first two years of tertiary education are thus devoted to 'engineering sciences', which serve as a foundation for analytical thinking where students are required to apply scientific principles to technological problems [4]. One way of addressing this challenge is to augment third-year mining students' professional development course by exposing them to (a) a variety of enquiry tools linked to the different types of problems that engineers typically experience every day and (b) provide a model to guide lecturers and students in connecting different enquiry tools so as to develop their internal-external integrative cognitive behaviour. The purpose of this paper is twofold.

First to outline a small-scale design-based research project in progress attempting to understand the use of enquiry from an extended cognition perspective and second to connect such enquiry behaviour with broad types of problems, while aiming to draw implications for engineering education in general and for mining engineering professional development at UP in particular. The first phase of the project, outlined here, entails defining a suitable generic theoretical framework that can be applied to the early phases of the design process across disciplines and levels of expertise. Extended cognition, approached as an information-processing system of which enquiry plays a central role when solving problems, serves as a theoretical framework. The second phase comprised gaining information regarding expert design behaviour through empirical protocol studies applying mixed methodologies. The third phase, which is the dominant part of this paper, involves the initial stages of mapping of extended enquiry onto problem solving models accepted in both engineering industry and educational contexts.

2 PHASE 1: DEFINING A SUITABLE THEORETICAL FRAMEWORK

2.1 Extended cognition

One of the challenges of developing enquiry skills in design education is to foster students' independent abilities to direct their enquiry towards their own internal as well as external sources, while learning how to access and utilise relevant knowledge in ill-structured problem solving tasks [5:527]. Extended cognition is useful as it connects well with what the author regards as enquiry skills relevant to problem solving (discussed further on) and which are typically required during the early phases of the design process [6]. Internal information processing is here considered to be the internal accessing, connecting and using of stored knowledge and embodiment principles, including intention-attention and its synergistic integration with external sources and processes based on the fundamental problem solving requirement of intention [7]. Identifying engineers' intention-attention actions implies answering the question related to 'how it might be possible for designers to act on their perception'. Key to understanding how effective enquiry skills can be developed is establishing engineers' intentional reaction to perceived external clues in their environment that could provide information that would assist their problem structuring and problem solving efforts. The implication is that internal knowledge as information and embodiment principles are operating interactively. It does not fall within the scope of this paper to discuss all the potential internal and external sources of information and how the interaction functions, but these can be viewed in the original study, documented in a PhD thesis by the author [8].

Characterising *early phases* of problem solving

Rather than taking place in linear and sequential steps, problem solving is thought of here in terms of cognitive phases, as explained by Goel [7] and expanded on by the author elsewhere [6]. Two distinct cognitive phases, namely problem structuring and problem solving, are typical of the early phases of the design process. However, these two phases at times break down into a 'leaky' phase, which refer to an overlap between the phases. The notion of cognitive phase implies multiple internal and external enquiry activities from which designers, by applying their loose control structures, personal stopping rules and evaluation functions, select what should be explored, and what information should intentionally receive their attention. It is during these phases that designers' enquiry skills play a central role.

Problem structuring phase

The typical design problem in its entirety is ill-understood by engineers when they start engaging with it. This means that the information provided in the design brief is insufficient, implying that the information in this 'starting state' is insufficient. During this first phase, engineers typically attempt to understand the problem. During this phase they establish what they know and what they do not know. They enquire about people, objects and the context in which the given problem is situated [6]. As such, the notion of 'problem structuring' means that they try to understand the problem, what its scope is and what its constraints, requirements and specifications are. This phase requires designers to look for relevant information in various places – internally and externally.

Problem solving phase

The second distinct cognitive phase at issue here involves the equally complex problem solving phase. For Goel [7:97] this phase consists of three sub-phases, namely preliminary design, development and refinement. Broadly speaking, designers attempt to solve the given problem through constant enquiry about the interrelations between people, objects, and context while generating ideas, developing preliminary solutions, manipulating and transforming models [8]. They typically delay commitment and decision making in order to continue evaluating their choices in terms of functional and behavioural fitness for purpose, applying domain-specific knowledge and personal knowledge [9]. During this process they communicate their ideas in various ways including talking, writing, sketching and modelling, which they actively and concurrently use and manipulate to represent their developing thought processes. Goel [7] identified twelve psychological features prevalent during the early phases of expert designers' design process. For this paper, I consider three salient characteristics which are lacking in engineering education literature but seem to play a central role in expert design enquiry.

2.2 Salient psychological characteristics of enquiry

Three psychological characteristics, including control structures, evaluation functions and personal stopping rules are focused on here for their close cognitive association with the enquiry process. Their logical connection with critical thinking and creativity, and the implied movement between the internal and external world of engineers, necessitate an understanding of these underlying psychological mechanisms.

Control structures

A typical understanding of designers' control structures is one of looseness, which implies that expert designers have an extraordinary openness to considering multiple contexts[1]. Goel [7:92] explains that designers typically use a limited-commitment-mode control strategy that can enable them to generate and evaluate design components in multiple contexts. Closely connected to this understanding is documented evidence of designers' ability to increase their heuristic enquiry of design aspects, as they demand access to and use of alternative information sources [10, 11]. Most decisions by experts result from past experience and memory of similar cases [1].

Evaluation functions and personal stopping rules

Evaluation functions play an important role in designers' judgements of suitability while personal stopping rules represent their subjective preferences that interact with their domain specific knowledge when they enquire alternative possibilities and making decisions. These rules are bound to designers' personal beliefs, preferences and philosophical viewpoints. As there are no right or wrong answers in designing, and no real direct feedback from the world, the evaluation functions and stopping rules driving designers' enquiry are derived from their personal experience and degree of immersion in their projects. Goel [7] maintains that the questions if and when a designer considers a certain design component to be complete and whether it is a fit for purpose solution to the problem, are questions typically determined by the designer and not necessarily in line with the logic structure of the problem. These decisions are essentially founded on automatic evaluation in terms of personal preference and experience, professional standards and practice, and, ultimately, client expectations. Flexibility here helps designers to move the focus of their enquiry coherently between their own preferences and the preferred requirements of clients, which often conflict with their own, adding to the ill-structuredness of their problems [1]. By connecting these psychological characteristics with a theory of enquiry during the process of identifying, accessing and using internal and external sources of knowledge, it is possible to construct a framework that can guide the design and development of suitable learning opportunities in engineering education.

2.3 Enquiry-based reasoning

Enquiry as a form of learning is seen here as a central tool to gain information. As such, it has its origins in science education and was based on the recognition that science is essentially a question-driven, open-ended process and that students should acquire personal knowledge [12:392] when attempting to understand the fundamental nature of scientific reasoning. The argument in this paper is that by developing engineering students' connections between their psychological mechanisms in an extended task environment, we can start fostering the effective enquiry skills that are necessary to structure and solve engineering problems. It makes sense, therefore, to apply a learning theory in

[1] The converse of 'loose' control structure is 'tight structure', which is typically found under scientific experimental conditions where instructions and other aspects of laboratory control define 'boundaries' that limit the behavioural options of participants… Design experiments do not comply with these conditions, and as the boundaries provided in design briefs are insufficient and ill-structured, the control structures of designers are loose, giving them much freedom.

engineering education that assists in guiding the cognitive activities involved in enquiring tasks. For this study, I use an adaptation (Table 2) of Edelson, Gordin and Pea's [12] understanding of the cognitive function of enquiry in a problem solving context:

Table 1. Principles of enquiry, enquiry activities and their relation to extended cognition (adapted from [12:394]

Enquiry principles + Locus of enquiry + Psychological characteristics	**Cognitive activities**	**Expected links with cognitive phases**
Problematisation Internal and external enquiry. Determine gaps in information provided in start state.	Enquiry activities can lead students to discover the scope and nature of a given problem. This includes enquiry about people, objects and context relevant to the given problem.	Problem structuring phase.
Demand Internal and external enquiry as a result of insufficient information provided.	Successful completion of engineering tasks require domain-specific and generic design knowledge including conceptual, procedural, visualisation, normativity and adequacy knowledge.	Problem structuring and problem solving phase.
Discover and refine Internal and external enquiry reacting in cycles known and unknown information. Apply personal stopping rules, evaluation functions and control functions.	Pursuing answers to questions can enable students to uncover new domain-specific conceptual and procedural knowledge as well as new generic visualisation, normative and adequacy knowledge assisting their design methodology and decision making.	Problem structuring and problem solving phase.
Application Professional and personal judgment of relevance and intentions. Internal inquiry into personal stopping rules mechanising choices and decisions making.	Engineering requires application of domain-specific and generic knowledge in the pursuit of solving the given problem including conceptual, procedural, visualisation, normativity and adequacy knowledge.	Problem solving phase.

In order for these principles to be successfully learned, Edelson et al [12] suggest that lecturers consider the following suggestions for creating a suitable task environment in which enquiry can be learned:

- Enhance interest and motivation
- Provide access to information
- Allow active, manipulable representations
- Structure and guide the process with tactical and strategic scaffolding support
- Manage complexity and aid production.

These principles of enquiry and requirements for effective enquiry-based teaching could be used in a variety of ways, depending on the level of independent thinking of the class at a particular stage in their course [13] as a generic guideline to selection of particular suitable mental tools in engineering education. It is suggested that a thorough matching of such tools needs to be carried out in a scientific manner in order to establish an epistemologically authentic guideline for enquiry tasks in engineering courses. In the following section I discuss the educational implications of the afore mentioned empirical study [6] on expert design behaviour, which represents the second phase of the overall curriculum design project and informs the third phase thereof.

3 PHASE 3: RECOMMENDATIONS FOR DEVELOPING CURRICULUM

It is a well-researched fact that workplace problems are typically ill-structured [1, 7]. The notion of an ill-structured problem refers to the fact that the problem solver does not have sufficient information at the beginning of the process to know exactly where the boundaries and complexities of a given problem are. It means, moreover, that new and unexpected elements and constraints emerge during the problem solving process that render the entire problem solving process unpredictable. Design problems are typified as such kinds of problems. However, not all engineering problems are design problems. Some entail purely technical repair tasks, while others require refining or improving existing systems or artefacts. In contrast, design tasks require the planning of non-existing systems or artefacts which have never before been created and for which no known solutions or constraints therefore exist. At the heart of the categorising of problems here is the potential for unknown constraints to emerge during a process of problem solving. Whereas some problems might appear well structured at the start, constraints and unanticipated problems incrementally become apparent, which change the nature of the problems to ill-structured [1, 7]. It has furthermore been found that, within large-scale engineering refinement and design projects, multiple well-structured problems are embedded in the overall ill-structured task. However, although engineering students are used to solving well-structured problems, these kinds of problems are rare in everyday work practice. The need therefore exist mapping extended cognition, psychological characteristics and enquiry principles onto existing engineering approaches towards problem solving in order to identify learning opportunities for students that would foster their mental abilities to connect existing knowledge with information through direct observation within the boundaries of particular types of problems. In Table 2 an attempt to theoretically map enquiry into three broad categories of engineering problems is presented; this is currently being used to guide tasks in the professional development course of the said mining engineering group of students.

Table 2. Mapping enquiry tasks onto categories of engineering problems

CHARACTERISTICS	**CATEGORIES OF PROBLEMS**		
	Repair	**Refine/ Improve**	**Design/ Innovate**
STRUCTURE OF PROBLEM →	Well-structured Simple	Ill-structured + well structured Complex	Ill-structured + well-structured Extremely complex
Problem space: Starting point of enquiry	Problematise: Find the faulty component; Presenting symptoms	Problematise: Existing system; Search for areas in need of improvement	Problematise: Need; Intentions; Required behaviour; Impact; Brief; Community; Environment
Focal point of enquiry	Demand: Find causes of fault; Constraints are known	Demand, discover and refine: Constraints, restraints, modification to artefact/system, interaction with people and context	Demand, discover and refine: Constraints, restraints, required structure/system, behaviour, interaction with people and context
Core reasoning process	Corrective measures: Application of known domain-specific knowledge	Analysis, evaluation & refinement: Application of known domain-specific knowledge	Design: Discover & refine unknown and known information
Sources of information	Internal domain-specific knowledge recalled from memory; External information accessed through visual perception of current problem situation	Internal domain specific knowledge recalled from memory; External information accessed through visual perception of current problem situation	Internal domain-specific knowledge recalled from memory; Internal knowledge from personal experience of similar and different problem situations; External information accessed through multiple direct perceptions of current problem situation and its constraints
Solution space: End-goal of enquiry	Put things back the way they were	Improve physical & procedural characteristics of existing systems/objects	Create something innovative; Potential for multiple unknown constraints

Sources of information	Internal domain specific knowledge recalled from memory	Internal domain specific knowledge; internal knowledge from personal experience; Internal knowledge from personal experience of similar and different solutions; External information accessed through multiple direct and indirect perceptions of current problem situation	Internal domain specific knowledge recalled from memory; Internal knowledge from personal experience of similar and different solutions; External information accessed through multiple direct and indirect perceptions of current problem situation

Table 3 presents a summary of the guidelines for lecturers for formulating suitable problems to develop the different levels of enquiry knowledge needed to solve typical engineering problems. Repair problems are not considered, and the focus is primarily on refine/improve tasks and design problems.

Table 3. Implications for engineering education to integrate extended cognition, enquiry and categories of problems

INTEGRATION	**CATEGORIES OF PROBLEMS**	
	Refine/ Improve problems	**Design/ Innovate problems**
Enquiry principle	Problematise; Demand knowledge; Discover and refine knowledge; Apply knowledge	Problematise; Demand knowledge; Discover and refine knowledge; Apply knowledge
Task environment requirement	Provide access to internal and external information in problem structuring and problem solving phase; Allow active, manipulable representations in problem structuring and problem solving phase	Provide access to internal and external information in problem structuring and problem solving phase; Allow active, manipulable representations; Structure the process tactically in problem structuring and problem solving phase; Manage complexity and aid production
Psychological characteristics expected	Control structures Evaluation functions	Control structures Evaluation functions Personal stopping rules

4 CONCLUSION

This design-research-based study outlined the first and third phase of an ongoing engineering curriculum design project. For this purpose, the first phase extended cognition is identified as a suitable theoretical framework for the project. It was shown that extended cognition implies the integration of internal and external sources of knowledge and information processing. The advantage of this framework is its ability to assist in empirically identifying typical expert design experiences during the early phases of the design process, when engaging in ill-structured problems that could be mirrored in engineering design curricula. The second phase of the project, methodology and results of an empirical study, informing the project, falls outside the scope of this paper. The author identified enquiry-based reasoning as a pedagogy suitable for fostering key psychological characteristics when applying the extended cognition framework. The implication for engineering education is therefore that lecturers should strive to identify suitable engineering problems that are sufficiently ill-structured to allow students to engage in enquiry tasks including problematisation and demanding information during the cognitive phase of problem structuring, and demanding, discovering, refining and applying information during the problem solving phase. These tasks should be sufficiently interesting and complex, be supported with access to information, allow active, manipulable representations, be structured and provide tactical guidance and enable the management of its complexity and production. It is finally recommended that the theoretical and practical opportunities for the development of psychological characteristics be further investigated. The theory of extended cognition requires empirical comparative studies determining students' application of control structures, personal stopping rules and evaluation functions. Furthermore, a careful mapping of the epistemologically authentic enquiry into the problem solving tools typically used in engineering education including TRIZ, Kepner-Tregoe and CDIO needs to be undertaken theoretically and tested empirically.

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PROBLEM FRAMING AND DESIGN OPPORTUNITIES

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ABSTRACT
A comprehensive study of early childhood injuries undertaken by Nationwide Children's Hospital in 2010 revealed that the common household spray bottle was the most likely source of injury for young children under the age of five. Due to the size of their hands, small children typically point the spray nozzle directly at the eyes and mouth when attempting to actuate the trigger with both thumbs.
Nationwide Children's Hospital contacted The Ohio State University seeking help with a new trigger design that would effectively eliminate the spray bottle as a source of injury. A design and engineering team conducted additional human-centred research and found a range of alternative design opportunities that could reduce the number of injuries caused by household cleaners. The hospital team was interested in developing a solution to the design problem as they defined it. The design team, following the directive of the Hospital team, proceeded to design and prototype a successful two–stage-triggering mechanism that is currently going through the patent process in the USA. This design was tested and found to meet all the requirements set by the hospital's design brief.
Although the design of the mechanism was successful from a functional standpoint, it has not as yet been adopted by industry. This paper presents a critical case study of the process by which the re–designed trigger mechanism was created, paying special attention to the "framing" of the design problem and the limited understanding of market constraints faced by the hospital and design teams. We believe this case study represents a useful example of how addressing a compelling need through a good design solution translates to a commercially viable alternative in the market.

Keywords: Problem framing, design constraints, market constraints.

1 BACKGROUND

A study conducted by researchers from the Centre for Injury Research and Policy at Nationwide Children's Hospital, concluded that household cleaning products are responsible for many accidental poisonings in children. Household cleaning products are consistently in the top five categories for paediatric poisoning exposure. An estimated 268,000 children were treated in US emergency departments for household cleaning product-related injuries during a sixteen-year period. The number of injuries attributable to household cleaning product exposure decreased 46.0% from 22,141 in 1990 to 11,964 in 2006. Children 1 to 3 years of age accounted for 72.0% of cases. The primary mechanism of injury was ingestion (62.7%), and the most common source or container was spray-bottles (40.1%). Although rates of household cleaner-related injuries from regular bottles or original containers and kitchenware decreased during the study period, spray bottle injury rates showed no decrease [1]. Recommendations from the American Academy of Paediatrics include storing poisonous substances in locked cabinets, buying products with child-resistant packaging, keeping products in their original containers, and properly disposing of leftover or unused products [2]. After publishing this study, the researchers received considerable attention from the media due to the significance of the numbers associated to a device commonly perceived as harmless. The researchers, compelled by what the data from the study revealed, decided to pursue a redesign of the current spray bottle. An additional motivation was the earlier success of the cigarette lighter safety mechanism. As a result of the change in design and the development of the child-resistant lighter, there was a 58% reduction in fires caused by children under the age of five in 1988 [3]. This policy began as a voluntary standard but eventually became law in 1994 (16 CFR Part 1210). The immediate goal of the research team from Nationwide Children's Hospital was to develop a spray bottle trigger mechanism that greatly resembled the locking mechanism of the child–resistant cigarette lighter. The long–term result of this product would be i) to significantly reduce the number of injuries and ii) to encourage the implementation of a similar policy standard as that of the cigarette lighter. With this initial data, the hospital team defined the design problem and sought design expertise from the Design Department at Ohio State University.

2 THE DESIGN PROCESS

The University team was comprised of two Industrial Design Faculty, one Mechanical Engineering faculty and one design graduate student. The hospital and the university have a well-established research collaboration agreement; initial funding for the project came from the research fund from a member of the hospital team. During the initial project meeting the design team led a discussion with regard to the problem definition. In short, the design team wanted to explore the problem space beyond the trigger mechanism. They felt strongly that a need existed to understand what other elements were influencing children's behaviour, given the fact that all spray bottles were already equipped with a safety mechanism on the nozzle. The design team felt that understanding use, misuse, and storage, product, and user interactions was a crucial factor in the success of the project. A need existed to expand the framing of the problem from a narrow focus on the trigger mechanism to the larger context of use if the ultimate goal was to reduce injury from chemical exposure due to use of spray bottles in children five and under.

2.1 Research

The design team's initial task was to persuade the hospital team to further explore the problem space. This is often a challenge when working with scientists whose research focus often lies in exploring solutions to relatively well–defined and understood problems. In contrast to science, design treats both the problem *and* the solution as something to be explored [4]. To address the need to explore the problem space, the design team requested additional research and developed two protocols for in-home observation and parent-child focus group/interview sessions at the hospital's research lab. The hospital team followed the protocol and conducted home observations with twenty-five families of young children, and conducted interview sessions with nine randomly selected families. In the home observations a total of 36 percent of all cleaning product containers were identified as spray-bottles (n=238 spray-bottles in twenty–five homes). Of those spray-bottles, a total of 75 percent had nozzles that were not in the closed or off position. The storage areas were cabinets in kitchens and bathrooms, closets, pantries and laundry rooms. Cleaning products were found alongside sport drinks, foods, soaps and beauty products and the locking systems were mostly disengaged. Parents were asked to clean a surface while the process was videotaped and later analyzed by the design team. During the lab observations, children ages four to five were asked to clean a table and were given five different types of spray bottles filled with water in the "on" and "off" position.

Figure 1. Lab Observations

Most of the children were able to turn the locking nozzle from the "off" position to the "on" position, but had difficulty actuating the trigger due to a lack of strength, reach, and dexterity due to their small hand size. Most of the children were quite inventive, and developed strategies to overcome their inability to trigger the mechanism by engaging their body in the effort, turning the bottle and facing the nozzle in order to engage the trigger with both thumbs, as shown in Figure 1.

From these research activities, the design team identified a range of design opportunities beyond the trigger. Limiting access to chemicals by children can be achieved through a number of different strategies, including a safer package, a different dispensing system, a different set of cabinet locks, a different colour chemical (that clearly differs from sport drinks) or a combination of those. We summarized our findings through the use of visual diagrams and mindmaps (Figure 2).

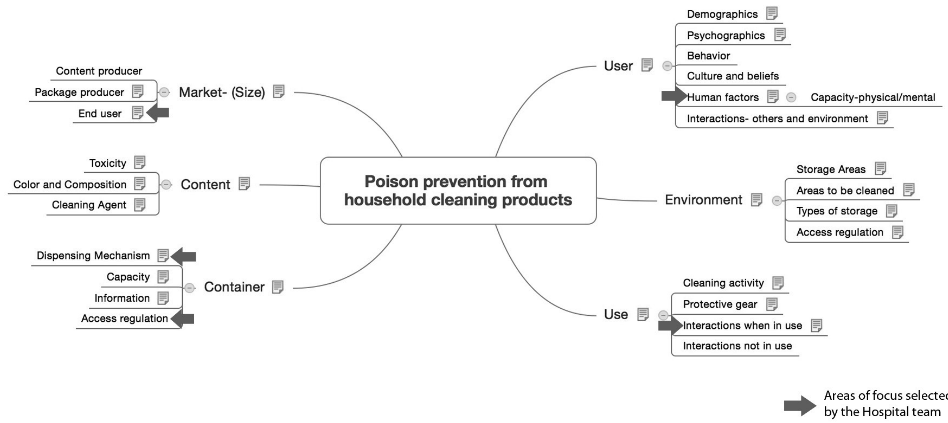

Figure 2. Problem Opportunities Mindmap

These ideas were presented to the hospital team as complimentary to the trigger direction but the hospital team further constrained the problem definition by insisting that the design: i) must meet the US Consumer Product Safety Commission (CPSC) standards for child-resistance (non of the existing dispensers and spray bottles meet this standard), ii) must use a safety mechanism similar to the cigarette lighter's, and iii) must also require minimal expenditure on the part of any company that adopted the technology. The red arrows on Figure 2 highlight the areas of focus selected by the hospital team.

2.2 Design and Development

The design team proceeded to develop a solution to the problem as further defined by the hospital team. The expertise of the hospital team is in the area of behavioural research. The goals for the Centre for Injury Research and Policy are to improve scientific understanding of the epidemiology, biomechanics, prevention, treatment and rehabilitation of injuries [5]. Areas of focus include home safety and poison prevention. The Hospital team is dedicated to reducing injury-related paediatric death and disability worldwide. After identifying compelling numbers of injuries through the initial research effort, the spray bottle was identified as the most obvious and effective way to addressing the problem. However, there is a gap between identifying a compelling need and defining an effective product development brief. One of the challenges of our collaboration was to educate the hospital team on the design and development process but more importantly, to educate them on the constraints that the problem as defined presented. In an earlier paper [6], we outlined a system for organizing design constraints that we have successfully taught for many years at our University. This system places all constraints into one of five distinct categories: market, physical, technological, cultural, and usage. In developing our concepts for the new spray mechanism, our research led us to concentrate primarily on physical, technical and usage constraints. Several constraints of *use* came into focus when the design team observed parents of toddlers using spray bottles in the home, some of which had been overlooked by the hospital team. First, parents with small children often were forced to deal with more than one child at a time: the persona/scenario we developed involved a young mother holding an infant while working in the kitchen in the presence of a very observant toddler. This led us to conclude that one–handed operation of a device that would automatically lock upon being replaced on the kitchen counter was essential.

Further, we realized that strict *physical* constraints existed that we could not ignore. The redesigned spray mechanism clearly needed to be compatible with existing bottle dimensions, would almost certainly be injection molded from polystyrene or a similar thermoplastic, and ideally would require as little re–engineering of the spray mechanism as possible. In the United States alone, over two billion spray bottles are sold every year; a new design that required a major redesign of the basic pumping mechanism thus had little chance of success. This basic design, which has been in use for several decades, employs a simple spring–loaded piston/cylinder arrangement with two one–way valves to force liquid from the reservoir through the nozzle. With this in mind, we constrained our design concepts to those that could be readily integrated into this market–dominant design.

One major hurdle we had to overcome was the hospital team's fixation with the cigarette lighter locking mechanism. The design team understood that cigarette lighter lock was a two-step locking system that couldn't be directly implemented on the spray bottle in its initial form. On the cigarette lighter, in order to actuate the igniter, the locking mechanism has to be disabled. This is a difficult task but it is appropriate for the cigarette lighter because its use is only for the instance in which the lighter "lights" something. With the spray bottle, the context of use was very different. The spray needs to be activated multiple times while holding a bottle full of liquid with one hand.

Figure 3. Prototypes

We developed multiple concept sketches for a self–locking device that could be easily activated with one hand and that didn't require much strength to activate. An additional objective was to be inclusive of aging adults. We presented the sketches to the hospital team but we couldn't move them past the cigarette lighter design. We then proceeded to demonstrate the problem with quick prototypes that depicted the physical constraints on the hand and use of the cigarette lighter (Figure 3).

Only after experiencing the physical difficulty of holding the bottle and activating the trigger, were we able to convince the hospital team that the analogy to the cigarette lighter was valuable in its function but not its form. After building different prototypes and quickly testing them with a five year old boy, we settled on the design shown in Figure 4, in which the user unlocks the trigger by depressing a lever at the rear of the spray head, thereby forcing the 'shroud' to retract laterally, thus releasing the trigger and permitting use. The shroud is spring loaded, returning to its original position and locking the trigger upon release. The rear lever is intended to blend into the shroud as much as possible, thus concealing its function from alert four–year–olds.

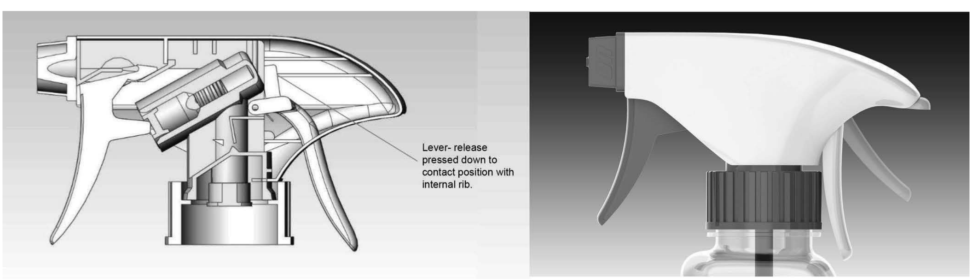

Figure 4. Final Design

3 THE COMMERCIALIZATION PROCESS

Once the final design was approved and the patent process begun, the question of commercializing the invention immediately arose. After negotiation, Ohio State University agreed, and the commercialization staff at the Hospital began the search for interested customers. This process began with very high hopes, because both the Hospital and University teams felt that we had confronted a compelling problem and solved it efficiently. The legal team further assured us that there did not seem to be any prior patents that would stand in the way. Our design appeared to be destined for success when considering the very large market of spray bottles.

The commercialization team began immediately to market the design to major manufacturers of common household products in North America, specifically targeting the very largest manufacturers or brands. After an initial flurry of interest (which included quite a few mentions on the Internet, CNN, and national and local newscasts), these firms backed away from the concept. The commercialization team then approached the small number of firms who manufacture the actual spray mechanisms, and met a similar response. The initial utility patent was issued in November 2011, but interest in the device from industry was minimal at the time.

4 THE FRAMING OF THE PROBLEM

With the benefit of hindsight, how could we have solved this problem in a manner that resulted in an immediate response from industry Thinking strictly in terms of a *solution to the problem as we understood it*, it is clear that we were successful: our design prevented young children from injuring themselves, while still allowing a young mother to use the bottle with one hand, while being assured that the trigger would re–lock the instant she put the bottle down. The problem actually is not with the design, but rather with how the original problem was framed. Rather than ask how to prevent young children from poisoning themselves, the hospital team immediately (and understandably) focused instead on the device that the child was holding when they were injured. Rather than ask, “How do we avoid this situation?” they asked, “How do we make this device safer for small children?” Initially, the design team attempted to widen the frame of the problem in order to explore alternative areas of focus but the hospital team was convinced that the scope they identified was the appropriate problem to solve.

In effect, at the inception of the process, Nationwide Children’s Hospital looked at one of the indicators of the problem before writing the design brief. They reported high numbers of patients presenting injuries sustained from spraying themselves in the eyes. The research data was collected from emergency room reports but there was no data available from parents to find out if the access to the spray bottle in the home was rectified. Also, there was no record of any of the patients being re-admitted with the same issue a second time. This check would have indicated if the parent took responsibility for the accident and modified the home environment. The assumption was made that by changing the spray bottle without considering the perception of the problem and the complexity of the market, the situation could be corrected in the same way it was with the implementation of the lock on the cigarette lighter. The primary difference is that with the cigarette lighter, the effects of misuse are significantly worse and parent’s acknowledged the deadly consequences. The perception of danger from spray bottles is low and thus there is less sense of urgency from parents.

In terms of the market, the constraints were not as clear for either team. The primary consideration given was the number of spray bottles currently sold worldwide but the business model that supports the packaging industry works differently from that of a standard product. Both teams overlooked the fact that the bottle manufacturer is an intermediary. The consumer goods company that manufactures the chemical formulation purchases a spray bottle from a supplier of bottles. The spray bottle supplier is only beholden to their customer: the consumer goods firm. This firm believes (along with their attorneys) that the warnings on the label indemnify them from liability if the end user puts the bottle within reach of a child. Additionally, they claim the twist lock is an *anti-leak feature* that was *never intended as a childproof system.* When there is a claim, there is a higher risk for liability. The bottle/sprayer supplier does not carry any liability because they are a sub-contractor and only react to their customer, not the end user. They are also not responsible for what is placed in the bottle. If either company offers a child-resistant product they immediately assume liability, so rather than offering a feature to improve the life of their customers, by adopting our improved design they would also be acknowledging responsibility for its use. The current system is better for both companies because the responsibility of keeping the chemical away from children is placed on the parent.

To the best of our knowledge, consumer product companies have not been sued, thus there is little or no motivation to pursue a mechanical solution, nor even acknowledge that there is a potential problem with the existing bottle by entertaining the notion of changing the design and thereby opening a new area of risk exposure. Further, the bottle suppliers are also not motivated to re-tool a new bottle when their customers will not purchase it and do not demand it.

We believe our design is effective in keeping children safer and does not represent a major investment for any consumer product company. We also believe that companies shouldn’t offer toxic products in packages that can be accessed by kids. However, the fact that no lawsuits have been filed against companies does tell us that the perception of the problem by parents is a major hurdle in addressing it. Understanding perceptions and the parents' sense of accountability should have been at the center of our inquiry. This information would have allowed the design team to shift the focus from the bottle to the environment. If the problem had been framed as finding a solution that can limit access to chemicals by children under 5 years old, there is a good chance we would have considered alternative solutions for storage, safety mechanisms and locks in the home environment.

Even though the prospect of manufacturing our safer spray bottle has not been completely ruled out at this time, we believe that the case study shows an excellent design that faces additional hurdles in the commercialization process due to the lack of understanding of the market, the business model and the perceptions of the problem by the end users. This case study serves as a good example of how framing a problem by expressing product requirements in terms of mechanical functions rather than in contextual terms can limit product viability.

We have used this case study in our design and engineering classes for the past two years, and find that the students relate to it well, since the common spray bottle is an artefact that almost everyone has used at some point. This case fits very naturally into a discussion of constraints and problem framing, and allows us to explore options that could have resulted on either an alternative solution to the wider problem or a more effective commercialization process for our design.

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TOWARDS THE CHEQUERED FLAG: A COLLABORATIVE CROSS LEVEL ENGINEERING APPRECIATION CHALLENGE FOR BSC PRODUCT DESIGN STUDENTS

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ABSTRACT
This paper concerns pedagogic research, which explores the process and student benefits of a collaborative 'design and build' engineering team activity. The need remains, post Finniston, for students to engage in engineering appreciation activities to fulfil the requirements of the professional accreditation body and the academic learning outcomes pertinent to both knowledge and skills, which often results in students producing small products or components, which require the use of a range of engineering processes. However, students often fail to recognise the relevance of such outcomes, fail to visualise the three dimensional outcome, fail to appreciate the connections between design, detail, manufacture, materials and management, in what is often perceived to be a fragmented engineering workshop activity, limited in scope and lacking in connectivity to the students' studio projects.
Therefore, a fresh approach was taken with the delivery of engineering design and manufacture appreciation amongst the 1st and 2nd year undergraduates. Combining students from both 1st and 2nd year into mixed level teams that had to collaborate on a much larger design and build activity, utilising the knowledge and processes taught throughout the year as part of the activity. The design and build project centred on the construction of an engineered and designed 'soap box' racer that was trialled in a local park at the end of the summer team, such a competitive goal helped to focus and drive the students.
Teams were constructed of an equal number of 1st and 2nd years whilst female team leaders where recruited four per level to lead the eight groups in 2013 with mixed group leaders in 2014. Students worked in their teams over the course of 6 weeks designing and producing ergonomic rigs, before commencing work on the 'soap box' racers, which required the students to design and produce a rigid chassis, fully enclosed bodywork and fully functional steering and braking systems.
This paper documents the findings from the project in relation to the success of the project, student collaboration, the knowledge and skills gleaned, and future recommendations and lessons to be learnt. These findings additionally consider the students own evaluations of the project and their individual role within it, through a reflective piece of writing. Additional findings relate to the enhancements of cross level collaboration, which extend beyond the project, including how the first years benefited from the second year students' hindsight in preparation for the year ahead.

Keywords: Design education, engineering appreciation, collaboration.

1 INTRODUCTION

The project work described within this paper takes part within the context of Engineering Appreciation (EA1 & EA2) within the BSc Product Design course at Nottingham Trent University. EA1 and EA2 are undertaken in the 1st and 2nd year of undergraduate study, which corresponds to National Qualification Levels (NQF) levels 4 & 5. The course is which is accredited by the Institute of Engineering Designers, therefore the aim of the associated teaching and learning in EA1&2 is to partially fulfil the Engineering Council accreditation requirements for Engineering Practice [1] to the Incorporated Engineer level. Such criteria are concerned with the practical application of engineering skills, through fulfilment of the following criteria:

- Knowledge of contexts in which engineering knowledge can be applied (eg operations and management, application and development of technology, etc).

- Understanding of and ability to use relevant materials, equipment, tools, processes, or products.
- Knowledge and understanding of workshop and laboratory practice.
- Ability to use and apply information from technical literature.
- Ability to use appropriate codes of practice and industry standards.
- Awareness of quality issues and their application to continuous improvement.
- Awareness of team roles and the ability to work as a member of an engineering team. [1]

Teaching within EA1&2 is less formal than the traditional lecture, seminar or tutorial formats that are typically found within Higher Education; instead teaching focuses more on technical instruction of core practical and physical skills in an engineering workshop setting. Students typically engage in these activities within small groups in one morning or afternoon every other week. EA1 sessions typically require students to produce components from engineering technical drawings, which require them to obtain and practice skills related to machining and fabrication, through the use of lathes & mills both CNC and manual, taps and dies and sheet fabrication using welding and other permanent or semi-permanent jointing methods. Whilst these activities endow the students with an understanding of engineering processes as intended by the original Finniston report [2] and lately the Engineering Council requirements, it lacks relation to the rest of the degree programme, due to the elementary nature of such skills training in the 1st year. Therefore a new end of year project was developed for 1st year student to encourage them to apply their EA1 learning and integrate this within a design and build project linked to their studio teaching in integrated projects. The intention of such an activity was to encourage them to enhance the creative problem solving skills within the more engineering skills based area and to develop teamwork skills in collaboration with 2nd year students.

2 METHODOLOGY

The soap box challenge activity was run at the end of the summer term in 2013 & 2014 with initial design work being undertaken by the students over the 2 weeks prior to the build, designing the mechanical systems and producing ergonomic rigs for their designated tutor driver. The build took place over the preceding 3-4 weeks and the race day was held in the first week of June.

The design of the specific challenge was to encourage 1st year students to integrate their EA1 skills within their design projects element and manufacture components that they have designed rather than manufacture from drawing given to them. The challenge also focused on soap boxes so that it encouraged 2nd year students to implement and integrate their learning from their Applied Technology studies, designing mechanical components and systems and applying knowledge on bearings and friction. The challenge was run with mixed teams of 1st and 2nd year BSc Product Design students, 7 teams consisting of 9 students each participated in 2013 and 8 teams of 8 students participated in 2014. Students were permitted to select their own groups; however in 2013 female team leaders were picked 4 from each year group. This decision was made as there were far fewer female students in each year group with a ratio of 1:5, this lower number made the selection of team leaders far easier. Female team leaders were also chosen to promote female engagement in the challenge and ensure that it didn't become an activity dominated by a few competitive male students. However, as the findings detail having 1st year students as team leaders introduced problems and so for the 2014 challenge team leaders were elected solely based on academic merit and personal choice.

2.1 Challenge rules and constraints

The challenge was subject to a number of specific rules and constraints that students were briefed upon before they started. These covered numerous requirements and included the position of the driver who had to be seated in a feet first position; head first and lying down positions were banned. The steering was required to be a solid solution; rope pull steering for example was banned. The soapbox also had to have driver operated braking on a least one of the wheels, the driver also required a seat and to be enclosed and protected from moving parts such as the wheels or ground. A number of other specific restrictions were put in place for the 2013 challenge, including the requirement that the soap box had four wheels, which had to be of a specific size and were supplied to the teams. The soapbox also needed to be able to be flat packed for ease of getting to and from the testing site and for dismantling at the end of the competition. The soap box also had to be styled in the form of a 1930's racer. These final restrictions were removed after a review for the 2014 challenge.

2.2 Analysis

The findings of this paper were informed by the students' reflections upon the activity both in 2013 and 2014 as well as staff reflections and observations. The students were asked following the challenge to write a short reflective piece of writing limited to 2 sides of A4 on the success of the activity, responding to the following 6 questions:

- How did you find the brief, technical and practical requirements?
- How did you feel you worked as a team?
- How did the individual members of your team work and how was the team led or how well did you feel you led the team if you were the leader?
- How did you find the experience of working with 1st/2nd year students? Was this beneficial to you and did you learn from the experience.
- Did you feel that you applied your knowledge of engineering principles and practices?
- What did you feel that you learnt? This could be knowledge, management techniques, practical skills or social interaction.

The findings from these reflections informed the development of the challenge from 2013 to 2014 as well as the findings presented in this paper.

3 FINDINGS

The individual student reflections were considered by the lead author and the students comments and reflections were grouped accordingly to common themes that were derived from the questions posed to the students and the students own thoughts.

3.1 Use of EA principles

The use and practice of EA skills within the project varied between the 2013 and 2014 challenges. Due to the flat pack rules imposed on the build of the soap boxes in 2013 most of the construction required the use of non-permanent methods, with students largely using Dexion secured with nuts and bolts for the chassis see Figure 1. However, welding techniques were employed on aspects of the steering, and turning and milling were employed by the majority of the teams in order to machine the steering linkages as well as braking components in some cases. It was found that the relaxation of the rules in the 2014 challenge was much more suited to a wider use of EA techniques. The greater freedom in the rules, permitted greater creativity in the solutions and components manufactured, with more students demonstrating a wider range of fabrication methods and much greater uptake of welding in comparison to the previous year see Figure 4.

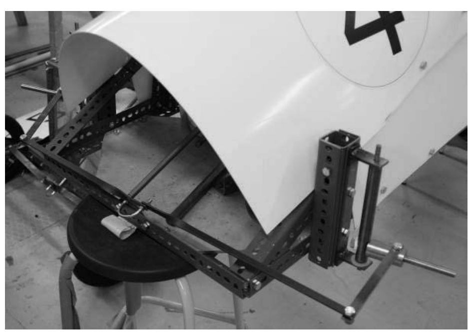

Figure 1. Soap box construction in 2013

3.2 Student Engagement

The exercise was found to be particularly engaging; however students struggled with effective time management and the freedom given in the 3-4 weeks of the build. As a result 2 soap boxes failed to run in both 2013 and 2014 challenges due to being incomplete or being deemed unsafe following a rushed finish. However those that did compete in 2014 were more reliable and successful demonstrating progression. Of the 6 soap boxes that were allowed to run in 2013 only 3 completed the route, whilst all 7 of those that were allowed to compete finished the route in 2014.

The activity fostered a very competitive spirit amongst the students, with all wishing to run their soap box and very high attendance on the final race day across both years despite it being the penultimate day of term. The activity also encouraged some students who previously lacked academic engagement to engage highly due to the practical and competitive nature and this increased engagement filtered through to enhanced attendance beyond the challenge. However some students who usually engaged well on other more academic aspects of the course took the challenge less seriously as it was seen as a fun rather than academic activity and this typically affected 2nd year students more than 1st year students.

The activity helped to build relationships between the two cohorts with 2nd year students sharing their experiences of looking for placement and dealing with the increased workload in 2nd year with their 1st year counterparts, whilst the 1st years' enthusiasm and in some respects fresh outlook and approach was beneficial to the 2nd year students also.

The choice of female-only team leaders in 2013 wasn't ideal as it was found that the 1st year students lacked the experience and confidence to lead the teams and even began to resent being the leader in two cases. In these instances the leadership was then assumed by a 2nd year male student within the team. Therefore in 2014 the criteria for team leaders was that it should only be 2nd year students who wished to lead a team for which there was a more representative gender distribution with one female team leader and 7 male team leaders, better reflecting the gender makeup within the course.

3.3 Innovation and Creativity

It was found that although the 'flat pack' approach to the racer's construction for the 2013 challenge was a practical one, it was very unpopular with the students who saw it as a restriction too far and felt that it negatively affected their teams and soap box performance. In addition to this, whilst a number of the students really got into the spirit of the 1930's racer style, a number also felt that the aesthetic styling requirements were constraining and detracted from time that would have been better spent on perfecting the mechanical aspects of the soap boxes.

Figure 2. Chassis twist on a 1930's style soap box

In light of this the challenge brief had fewer constraints in 2014, with no guidance on construction or styling, instead the students were asked to consider the reuse of materials within the construction of the racer and a major change also permitted the development of 3-wheeled soap boxes, which were previously banned in 2014. However, the main considerations of braking on at least one wheel, fixed solid steering and a feet first driving position were maintained in both years/ In addition for soap boxes to compete both the steering and brakes were required to be functional for safety purposes.

The reduction in the constraints in 2014 meant that there was far greater creativity and variety amongst the eight entries see Figure 2, which was surprising considering that the 2nd year students had already engaged in the exercise the year before and therefore could have been expected to revert to what they knew.

Figure 3. Variation in the 2014 soap boxes

A delay in the order of materials in the initial stages of the 2014 challenge also increased the creativity and innovation demonstrated by the students, using what they could find resulted in a significant increase in the uptake of upcycled elements, with a number of teams cannibalising abandoned bicycles, utilising frames, wheels and braking components within their creations see Figure 3. 3 out of the 8 teams chose to incorporate larger bicycle wheels within their soap boxes on either the front or rear axle as opposed to the smaller wheels that were supplied. This completely changed the dynamic of the competition and enabled the students to be more creative as well as requiring them to overcome new challenges that came with the larger thinner profile wheels such as a changed centre of gravity, the need to shroud the drivers, addressing the different bearing tolerances and excessive wheel camber and in one instance material fatigue and failure mid run.

Figure 4. Bike derived soap boxes 2014

4 FURTHER WORK

The soap box racer activity has been a useful and fun activity for the students and will be continued albeit only with 1st year students due to increases in cohort sizes. However alongside this activity further action has been taken to increase the engagement of students across within the engineering appreciation workshops. In the 2014-15 academic year more focused activities were implemented within the EA1 curriculum and these have been formally assessed for the first time by the technical staff. The activities require every student to make full use of the variety of machining and fabricating facilities and the decision to introduce formal assessment to be undertaken by the technical rather than academic staff was taken to increase the perceived importance and relevance of the workshops, granting greater autonomy to the technical staff. The result of these changes has been very positive

encouraging 100% attendance from students most weeks in an area of the curriculum that previously suffered from very poor attendance.
Furthermore the integrated approach that has been fostered between the engineering appreciation requirements and other aspects of the curriculum with the soapbox challenge will be explored further in coming years. For instance there is an intention to introduce an injection moulding project in future EA2 classes that would combine the study undertaken in integrated projects, materials and manufacturing and utilise skills obtained through engineering appreciation to produce simple injection mould tools.

5 REFLECTIONS

Whilst the soapbox challenge was successful in many respects, lessons have been learnt throughout the past two years of running the challenge. Predominately these include the failure of the academic staff involved to socially engineer the student groups to encourage female engagement and leadership. Across both 2013 and 2014 engagement from the female members of the course appeared consistent therefore the initial concerns regarding the involvement of the female members of the course were invalid. Furthermore whilst tightly constrained briefs can be very beneficial with a studio environment mimicking the reality of industry it was counterproductive in respect to a competitive design and build activity. The constraints within the 2013 challenge overwhelmed the students to the point that the variation and innovation in the soap boxes suffered, in much the same way as some critics consider modern motorsport to be afflicted by a prevalence of rules. The relaxation of the rules in 2014 made the exercise far more enjoyable to the students and improved the outputs of most teams.
With increasing cohort sizes on design and engineering courses in undergraduate study it becomes more difficult to be able to run and manage such challenges, however the opportunity for students to ‘get their hands dirty’ in design engineering has never been greater [3] and therefore such a practical focus must be maintained. The benefit of activities such as this soapbox challenge are not merely limited to an application of knowledge; the experience has shown that students really enjoy the community aspect of such activities as well as the opportunities and benefits arising from having to operate outside of their comfort zone, where they can’t hide behind abilities in CAD or sketchwork.

Figure 5. Final run 2013

Figure 6. Winning team 2014

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INCREASING THE ENTREPRENEURIAL SUCCESS OF DESIGN SCHOOL SPIN-OUTS

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ABSTRACT
Universities and Design schools prepare graduates in the principles of product development, through bachelor's courses in Product/Industrial design and Business. Through the course of a typical design school education the graduate will have developed skills in research, idea generation and design thinking methodologies to support the development of Final year project (FYP). The business school graduate will similarly undertake a FYP to showcase the accumulated skills from the degree course. The typical FYP will produce the first embodiment or business plan of the new design/business proposal, expressed through the academic requirements of the design/business school. The requirement at undergraduate level generally does not include preparation for spin-out albeit many projects may embody many the characteristic developments necessary. This research will trace the project development stages from initial briefing towards spin-out, focussing on the study of entrepreneurial methodologies and philosophies as observed through case-studies projects from business school, design school and entrepreneurs independent of college structures. The focus of the research will be to discern the characteristic philosophies and methodologies with particular interest in 'causal' and 'effectual' thinking as observed in the development process.

Keywords: Causation, effectuation, spin-out.

1 INTRODUCTION

This research will contribute to design education by studying a number of case-study attempts to spin-out, following graduation from design and business schools. A comparison with start-up attempts from outside academia will be made following similar case-study research. It will endeavour to learn from their spin-out experiences observed to develop an understanding of the philosophies and methodologies at play during spinning-out development, with a view to proposing an educational strategy for fostering successful spin-out development. The application of the proposed educational strategy towards successful spin-out will be outlined later in the research schedule. This paper will focus on the pilot case-study to determine the 'causal' and 'effectual' thinking and the extent to which it is used.

2 MATERIALS AND METHOD

Aims:

- Through an inductive exploration of actors in the field of design-led product development, the research will investigate the spin-out and start-up activities of a case-study project – "TackleMan".
- A series of semi-structured interviews with the Case-study spin-out companies will identify the methodologies and philosophies of the development paths
- A review of the literature will be undertaken to explore the methodologies and philosophies that are representative of contemporary product development in the field of product development and subsequent spin-out
- Through a study of a number of case-study company's, Causal and/or Effectual (or the extent to which it is both) approach to development will suggest an approach to a successful development process based on an accumulated examination and analysis of the accumulated case-study data

3 LITERATURE REVIEW

As the design-led project in question is associated with a final year graduation project, brought towards business development after completion of the bachelors degree, the design school methodologies and philosophies should be evident through the projects. The area for examination will be evaluated through Causal and Effectual thinking. While the two styles of thinking align roughly along traditional business school and design school philosophy and methodology respectively, a duality may be evident in practice. A study of the literature follows to explore contemporary product development thinking.

Prediction and control of the environment of product development may often be possible depending on the development phase in question, but, the early development phases are often characterised by a high level of chaos, Koen et al, (2001). It differs from the New Product Development (NPD) process of solving a problem through innovative steps and stages that from the beginning are quantifiable and documentable and rely on prediction and goal setting, (Cooper and Klienschmidt, (1987), Brown and Eisenhardt, (1995), Griffen and Page, (1996). This early phase is commonly referred to as the "fuzzy-front-end", (Koen et al, 2001; Khurana & Rosenthal, 1988; Kim & Wilemon, 2002) and is described as the time between the initial conception of the opportunity or idea and the state of readiness in development for design, engineering, manufacture and introduction to market.

Koen et al. (2001) discusses five (fuzzy) front-end elements to pre-development: 1. Opportunity Identification, 2. Opportunity Analysis, 3. Idea Selection. He suggests a methodology based largely on ethnographic primary research, and that much of the foundation for the methodology is myth and extrapolation from existing customer experience. This can be contrasted with a purist effectual method where there are no assumptions of predetermined market or user but relies on the actions of the entrepreneur resulting from new developments presented. Rational - Preserving the Status quo v Emotional - challenging the status quo.

In comparing the character traits of "efficient" versus "innovative" people in business, Von Stamm recognises that a combined approach that utilises both phenotypes is more likely to survive and to innovate. While an over dependence on the "efficient" will tend towards conservative practice and stifle innovation, the opposite is true of over-reliance on the "innovative" will tend towards unstructured development practice (Von Stamm, B, 2003/8).

Type A ('Efficient'): Attention to detail, present oriented, needing clarity and predictability, numbers driven, tight control, repetition, standards and procedures, failure = disaster

Type B ('Innovative'): Bigger picture, future oriented, accepting of (initial) ambiguity, uncertainty, visual, concept driven, autonomy, experimentation, open-mindedness and flexibility, failure = learning

She draws a relationship with designers as people with "an innovation-conducive mind-set" and discusses their propensity to experiment and deal with the uncertainty - "fuzziness". She defines 'design' as "the conscious decision-making process by which information (an idea) is transformed into an outcome. She goes on to say that "it is about exploring and experimenting, the core of innovation"

Tim Brown, the CEO of IDEO places design thinking at the centre of the innovation process, stating: "Design thinking is a human centred approach to problem solving. It is a process built from people (inspiration gained by looking and listening to them), prototyping (ideating quickly to make things real), and stories (getting things implemented by selling compelling narratives not 'concepts')".

Embodiment of the solution through product design may be dependent on a process with repeated iterative divergent and convergent loops resulting in the optimum solution (Buijs, 2003). The environment of the development process depends on an empathetic connection to the 'user', a human-centred design approach. Traditionally, a large design phase would result in the product offering and an introduction to the market. Product testing (probing and learning), beyond the design team and company environment verifies the process (market testing phase). Unless tested the process may rely on the validity of the research phase to determine the product market assumption.

Causal reasoning identifies a specific goal and an approach towards achieving this goal. Causal reasoning describes the classic NPD philosophy where the central premise is that "if I can predict the future (typical business plan) I don't have to control it". From a Causal perspective the development process applies a series of predicted stages in a plan, which includes the design phase, that assumes an outcome based on a perception of market 'needs'. The plan then acts as a roadmap/guide to control the environment and allow the development of the product for the identified market.

Effectual reasoning can be seen as the opposite of causal reasoning – "if I can control the future I don't need to predict it". This reasoning drives entrepreneurial success where, starting with only a set of ‘means’ (who I am, what I know, what I possess, etc.) and the process of deploying them, goals gradually emerge (Sarasvathy, 2001).

Four basic principles of Effectuation according to Sarasvathy;

“Bird in the hand principle” - Start with recognition of your means

“Affordable loss principle” – Determine what an ‘affordable’ loss rather than the attractiveness of the predictable up side

“Lemonade principle” – Embrace surprise from uncertain situations – remain flexible rather than stuck to existing goals

“Crazy quilt principle” – Form partnerships with a shared view of creating the future product, firm or market – don’t worry so much about competitive analysis and strategic planning

Kraaijbrink, (2008) suggests that the two models are the extremes of the entrepreneurial behavior and focuses on the differences between the two models to arrive at an objective and balanced view. He argues that neither model should be exclusively connected to pragmatism or the entrepreneurial process. He suggests that the linear (teleological) causal model is more useful in existing products and markets that suggest incremental innovation and the (pragmatist) effectual model is more suited to the new product markets where the environment is characteristic of discontinuous innovation.

Causation model: Ends are given; prediction means controllability, consideration of expected return, suitable for existing products and markets, views outside firms as competition and is a linear model

Effectuation model: Means are given; controllability reduces need to predict, consideration of affordable loss, suitable for new products and markets, view outside firms as potential for partnerships and is a cyclical model.

4 ANALYSES

Initiating a project in product development according to the academic demands of the Final Year Project (FYP) using the principles of ‘Human-centred design’ (Kelly, IDEO), the student selected the ‘field’ for attention and through ethnographic principles and practice identified the ‘problem’ to address.

Through an analysis of semi-structured interviews with the graduation project spin-out, an account of the development path is presented below. For the purposes of this paper the case-study pilot project will be referred to as ‘Tackle man’. An analysis of ‘causal’ and ‘effectual’ thinking as outlined by Kraaijbrink follows a chronological review of the case-study development path. It uses a coding strategy to identify ‘causal’ or ‘effectual’ philosophies and methodologies used.

Development stage description: Project selection
“It was through a process… there was that 3 months of time to find the problem” **Causal characteristics:** *Seeking to find the problem to define the approach and plan for future*
Effectual characteristics:

Development stage description: Problem definition
“I found that there was nothing for the tackle… everyone has that problem learning to tackle It became very clear, 3 if not 4 things that it had to be; human form, movement, resistance, challenging and educational” **Causal characteristics:** *Found through causal process of ethnographic research (academic requirement) – Open ended, objective and interpretive*
“It was just a gut thing telling me…” **Effectual characteristics:** *Reliance on instinct and personal judgement of facts presented*

Development stage description: Gathering knowledge
“…we had to do a research report and I went out to my old secondary school… It was conversation, a questionnaire, having a chat with them. I identified… the hardest issue was moving Everything fell into place. It was game play; all they wanted to do was play. They don’t want a 15 min lecture from the coaches, it is just active learning, and you don’t have to make it ‘educational’… you need a moving target” **Causal/Effectual characteristics:** *Interpreting research findings and proposing direction for development is a dual causal/effectual approach combining agile thinking, direction finding and action-based response (effectual) from a structured process defined in the project plan (causal)*

Development stage description: Generating ideas

"I built three dummies, a wooden dummy with carpet underlay, a 'Wavin pipe' with stones (in the base)… I was just messing around with the centre of gravity and I still didn't know what I was doing… asked them to go tackle… I remember going, this is not going to work but hopefully it will give me other ideas, see what comes out the other end"

Effectual characteristics: *Communicating understanding of effectual process where the action from direct experience is over-riding the need for a detailed plan. Belief in action, based on findings from the research phase, that embodying the 'needs' will drive new ideas and directions*

Development stage description: Understanding concepts

"I got a bit focused and got a loan off my mother and my 21st birthday savings that I put against it. I filed for patent shortly afterwards just with that basic concept I'm going to push on with this and see where it takes me".

Causal characteristics: *Following the causal plan of development of the concept but taking an effectual side-step to protect the IP based on 'gut instinct and hunch that the concept is good*

Effectual characteristics: *Even at this early stage of investment the decision to take a risk with life savings shows a belief in the concept that is probably based on a calculation of 'affordable loss' over risk or risk aversion*

Development stage description: FYP showcase

'TackleMan' refined concept with underpinning research and design phase documentation supports successful graduation

Causal characteristics: *The end of year Showcase marks the end of the academic phase where a largely causal plan (with effectual action and reaction to encountered stimulus) results in an embodiment of the 'TackleMan' product proposal*

"Filed patent on concept to protect the product during the Showcase"

Effectual characteristics: *Action taken beyond the academic needs of the project demonstrates entrepreneurial action to considered academic outcome – effectual response*

Development stage description: Start spin-out

"Look, this concept works and I have a patent on it but I haven't a clue how to manufacture it I was still playing rugby and the rugby club were still paying for my accommodation and giving me a small bit of money. I saved everything and put it all toward the patent when it came up in six months' time. We have it patent pending in all the major sports markets even Japan".

Causal characteristics: *Causal actions according to predictable outcome, however, it shows a level of effectual response to the outcome.*

Development stage description: Determining means

"You are the inventor, the business person, the accountant, the fund raiser, the web designer, managing and picking out the trade shows, it is dizzying but it is cool"

Causal characteristics: *Shows an organised outlook and nascent business structure. The causal and effectual are showing co-dependant importance*

"I got a bit focused and got a loan off my mother and my 21st birthday savings that I put against it. I filed for patent shortly afterwards just with that basic concept *I'm going to push on with this and see where it takes me".*

Effectual characteristics: *Acknowledging acceptance of unknown as a potential for advancement*

Development stage description: Prediction v control

"I'd identified the LEAP program as an opportunity to get on a start-up program. The LEAP program was ok, here's the path and you follow ... access the funding. I got two innovation vouchers, five grand a pop - three actually? I got an Enterprise Voucher from Limerick city enterprise board that was 20 grand, I got some early money from EI, that was 12.5 grand and that was all within the LEAP program, so if I wasn't there that probably wouldn't have happened"

Causal characteristics: *Taking advantage of causal structures offered with knowledge of effectual*

opportunities and advantages resulting from the program **Effectual characteristics:** *Clear decision to embrace causal structures such as , business plan (implies future planning based on targets, etc.) as a means to securing funding and partnerships*

Development stage description: Risk v affordable loss
"I went down the route with probably the biggest manufacturer here in rugby; got on very well with him, very keen to develop this, going to be a 'Name' product, "our guys can do it" and I said look are you sure? Oh we make rugby balls, which has all that stuff, don't worry. Their guys didn't have the expertise. Then it was a different conversation of a joint venture… Didn't work out" **Causal/Effectual characteristics:** *Managing risk and opting out of a partnership which did not bear fruit as hoped – gauging extent of 'affordable loss'* **Effectual characteristics:** "I got some made up in china and in hind-sight was never going to be anywhere near to the final product but what it did do was it showed our logo on a custom made prototype that people thought was a product"

Development stage description: Competition v Partnership
"Finally, a UK company that manufacture in Romania… for a year we were developing it, making different ones. They didn't realise they were in a development process... and I flew over 4 times to Bristol, brought my mentor for a bit of weight… but three weeks into it when the owner that I was working the whole way with, selling the bigger picture… blew up on me one day, I thought the project was over. It was really awkward for about 2 hours. It was very stressful but good. Six weeks later I was able to fly home with the final product" **Effectual characteristics:** *Developing partnership with potential manufacturer and developing an understanding that is built on reciprocal advantage*

5 RESULTS

The raw data from the pilot semi-structured interview with case-study ('TackleMan'), is divided into the chronological stages of the development process as described by the case-study actor. Each stage shows data from the interview as stated by the actor and interpreted by the researcher for its 'causal' or 'effectual' characteristics. Each stage shows an analysis of the reasoning behind the classification. Many of the statements from the raw-data show 'causal' and/or 'effectual' characteristics. Many reflect both causal and effectual thinking in that they are part of a structured plan to mitigate the risk through planning but also reflect the characteristics of 'control' by reacting to the effects of preceeding happenings. Through the interview it became clear that the patterns were not clearly 'causal' of 'effectual' alone. In particular there was a pattern of developing business plans as a way to win funding. Pragmatism dictated that using business plans to gain funding was important, however, it was clear that the business plan was not always used to control the future. Importantly, the building of partnerships was critical to the development process. Breakthroughs came from critical partnerships where the combined skills and specialisations allowed progress. Embracing chaos and the potential for unforseen positive outcomes was seen to be a character trait of the actors.

6 DISCUSSION AND CONCLUSIONS

Effectual reasoning, however, is an identifiable methodology used in the "fuzzy front-end" (early design phase). The seemingly chaotic nature of problem identification, ideation, concept design and refinement, particularly employ a brand of thinking and process that is effectual. The design phase is a strategy of identified phases that depend on the effectual abilities of the design team to act in a constantly moving and changing environment. Reaction to new inputs and dependence on associated players or partners are the hallmarks of design. This thinking mode is built upon a 'causal' structure that provides a level of structure that is necessary for essential prediction that in this case-study allowed for the acquisition of funding that otherwise would not have been forthcoming.

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AN INTERDISCIPLINARY APPROACH TO EMBEDDING THE GLOBAL DIMENSION INTO ENGINEERING DESIGN: EMPATHY, ENGAGEMENT AND CREATIVITY

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ABSTRACT
Education, and specifically engineering design, has a lot to offer in our efforts to promote and achieve sustainable human development (SHD). A focus on SHD can be enhanced by non-disciplinary and atypical learning environments that complement core engineering and engineering design studies. This paper presents a case study of an educational innovation resulting from a collaboration between an NGO and a university.

Keywords: Engineering design, global dimension, sustainable human development, engineering education.

1 INTRODUCTION

The 21st century has arguably brought some of the toughest and most threatening challenges to both the human species and the planet as a whole. The impacts of challenges such as climate change are bringing new levels of scrutiny to our interactions with the natural world. A paradigm shift will be required to move engineering design from a previous reality of infinite and plentiful resources to a world where in the face of increased demand, these resources are rapidly depleting, urbanisation is increasing the complexity of our society and there is more awareness of the interaction between the built and natural environment.

Sustainable Human Development (SHD) was established in the 1987 Brundtland Commission [1] as being a critical focus for the future of our environment and development. The concept centralizes the principle that any development activity should aim to meet the needs of the present, without compromising the ability of future generations to meet their own needs. However this ideology has failed to gain adequate ground-level traction in the engineering and development sector, with few engineers being exposed to the ideas of sustainable human development or the broader dimensions of sustainable engineering practice in a development setting during their university education or early industry-led career development. A renewed focus on sustainable human development (SHD) could re-orientate modern engineering design and allow engineers to work together for a sustainable global future. The education of engineers – in particular design engineers – needs to incorporate new skills, competencies and approaches to facilitate this shift.

The UK based charity EWB-UK (part of the wider Engineers Without Borders global movement) is attempting to tackle this issue within both the education and professional development of young engineers. EWB-UK wants to help develop a new generation of engineers with the ability to work in the complex setting of international development, bearing in mind the ideals of sustainable development. Building a working ethos and set of practices (which we will refer to in this paper as Sustainable Human Development or SHD) is a critical first step, and these have been termed the 'global dimension'. This involves critical enquiry and a creative approach to the local context of each and every problem tackled, with engineers in particular focusing on the impact of the social, economic, environmental and cultural dimensions of their proposed interventions, and developing solutions in collaboration with local communities.

The EWB Challenge has been developed internationally and runs in the UK, Ireland, Australia, New Zealand and Malaysia. It aims to provide a tool for universities to expose their engineering and design undergraduates to complex real-world design problems. With the strategic aim of encouraging universities to embed the ideals of SHD within undergraduate and postgraduate curricula, the EWB-Challenge is a novel educational initiative that incorporates a high degree of flexibility in delivery, allowing lead academics at each institution to navigate the complexities of externally accredited curricula and of institutional politics.

This paper will present a case study of the launch of a dedicated SHD course at Imperial College London, detailing student engagement with the material, the development of the course structure and content over successive iterations (via a process of action research) and some reflection on the founding principles of the engineering profession and how these might shape the engagement of students with this initiative.

2 INTEGRATION OF THE CHALLENGE AT IMPERIAL COLLEGE, LONDON

Undergraduate disciplinary learning at Imperial College is supported by a cross-faculty programme of study called Imperial Horizons. This offers course modules in business, languages, humanities and sustainable human development (SHD). We offer a structured three year programme of SHD modules collectively called our 'Global Challenges' field of study. We have integrated the EWB Challenge into our second year SHD curriculum, which offers students the opportunity to undertake an extended real-world SHD design project in mixed discipline groups. We have designed these modules to be complementary to core degree studies at Imperial, so we integrate a number of non-standard methodologies and perspectives to challenge the students to think outside their disciplines and to help them tackle the complexity and uncertainty of a real-world situation. The students work in mixed disciplinary teams, drawing on their individual knowledge and experience, integrating methodologies from social sciences, design and business studies and reflecting on their own relationship with problematic situations to create considered and hopefully innovative solutions.

3 PEDAGOGICAL RATIONALE

The Global Challenges (SHD) curriculum within Imperial Horizons has been designed with a coherent curriculum across all three years of study that share the following common core aims for our students:

1. To foster an appreciation of the value of interdisciplinary learning
2. To develop confidence in their ability to learn independently
3. To develop a realistic and evidence-based approach to global challenges
4. To establish effective team working and collaborative practice
5. To explore communication practices and develop core skills

Some of these areas are explored more fully below.

3.1 Collaborative Learning

Within our course design, there are two levels at which collaborative learning occurs. Firstly and most explicitly, our students are working in multidisciplinary teams, where they are expected to individually contribute their own experience and disciplinary perspectives to the team work.

Secondly, the students self-enrol in different learning streams, where they focus on a unique topic or perspective within the broader learning landscape of each year of study. However, all students work in the same physical space, and by aligning the conceptual elements of the curriculum so that they are tackled simultaneously by all students, we are able to encourage collaboration across the learning streams. This has been a highly rated element of all our courses, with students citing this as the best feature of the course in formal feedback. It means that students working on a practical engineering design, might take inspiration or input from a team working on a business initiative to tackle poverty within the same community.

3.2 Partnership Curriculum

All the Global Challenges courses are built around a partnership curriculum [2], where the students make significant choices about both topic content and the scope of their study. Academic rigour and parity across the courses are maintained by the integration of a number of key concepts that can be tailored to the context of the students' individual choices. Contributing to the idea of true partnership in learning, we work with the model of the 'ignorant schoolmaster' [3]. The course leader has general rather than specific development expertise, and the course tutors who support the student teams have no relevant development or engineering design experience. Instead, the tutors contribute their experience in independent working, motivation, research and project management. This arrangement means that staff and students are learning together, coming up against obstacles together and finding solutions together. We encourage a high degree of self reflection and reflexive practice of both the students and tutors, which in curricular terms is similar to the praxis curriculum described by Grundy [4] and the ideas of emancipation expressed by Habermas [5] and Rancière [3].

3.3 Interdisciplinary Methodologies

The use of interdisciplinary methodologies is critical to our course modules. We need to make sure that our modules offer material that is complementary but does not replicate any of the core content from any of the degree disciplines at Imperial (engineering, natural sciences or medicine). For this reason, drawing from social science and business methodologies provides the students with new perspectives and tools that they can use not only in this project, but back in the core disciplines and in their working lives beyond.

3.4 Developing Empathy

Goleman [6] describes three types of empathy- cognitive empathy, emotional empathy and empathic concern. Cognitive empathy relates to understanding another person's perspective and their mental model. We use a number of methods to begin to encourage our students to actively engage with an empathic approach to others. Students share their own experiences and actively reflect on the value of these experiences in their work. We use Peter Checkland's Soft Systems Methodology [7] as a tool for exploring the experience of an individual or group of individuals within a complex real world environment. The students create a series of 'rich pictures' – advanced mind maps that allow the students to quickly organize a lot of complicated and sometimes conflicting information – of the complex problematic situation. The students redraw this map as a series, each from the perspective of a different stakeholder within the community, imagining the 'worldviews' of the various community members. We also use 'empathy maps' to focus this exploration [8].

3.5 Enhancing Creativity

We encourage the students to use divergent thinking to enhance their creativity. It sometimes appears that the students are quite focused within their 'disciplinary channels', and they find free form creative activity quite tricky. As elucidated by Vosburg [9], divergent thinking is hampered by a negative approach. We have noticed that students find the idea of creativity quite intimidating and often believe that they will not be able to be creative. We provide the students with a range of creativity tools that they can try out, and encourage the students to keep a paper sketchbook of all their ideas.

4 DESIGNING A COURSE MODULE TO SUPPORT THE EWB CHALLENGE

Within the Global Challenges programme there are four learning strands offered to our second year undergraduates. The EWB Challenge is embedded in Design for Sustainable Development, but we also have a strand called Design for Economic Development (the focus is on business innovation to target poverty within a deprived community), Design for Local Sustainability (considering whether 'development' is an issue for 'poor' countries, or whether there is valid development work to be done in our own communities) and Visualising Global Challenges (looking at communication practices and public views of development activity). Design for Sustainable Development has been run four times, and via a process of action research, this has been refined and evolved to its current iteration. Our main aim is to enable the students to gain a critical understanding of a complex real-world community; to think empathically about the experience of individuals within that community and those working to help the community; and to creatively design a potential solution to a hardship faced by that community. We want the students to draw on the individual disciplinary expertise within their teams, and integrate this with a holistic approach to considering and designing for the community. Specifically we want the students to consider the 'global dimension' to design engineering in their projects – they must reflect on the economic, social, cultural and environmental impact and sustainability of their design.

To inform the action research cycle of iteration and review we have observed the students working and critically reviewed their submitted work, and conducted informal student interviews at strategic points during the module delivery and after completion.
There is not enough space in this paper to detail all the changes that we have made over successive iterations, but we would like to review two of these in detail.

4.1 Allocation of design brief

Despite providing our students with a design brief encompassing many potential areas of focus, an issue that had repeatedly challenged us, has been the students' drive to pick areas of the design brief that they could address with the least effort and most speed – of note, nearly all students choose to work in the water and sanitation (WASH) area of the brief, mostly designing a water filter by the end of the first session. We have determined via interviews that there are a number of reasons that feed into this decision making, including the perceived effort of the task (students would like the most marks for the least effort), the need to anticipate success (students are often unwilling to begin a task if they are not guaranteed a successful outcome), the self-assessment that they do not have the ability to be creative, and the fact that many of them see development work in their disciplines as relating mainly to WASH.
Students report a strong self-image tied to the ideals of engineering – with 'mastery' being a key concept for them and metric of their progress. They believe that they should be able to 'master' nature, or problematic situations, and often this is expressed as the imposition of a 'perfect' solution on an 'imperfect' situation. Shifting this emphasis is key to effecting genuine engagement with the complexities of the real world. Recognizing that students are working from this fiercely defended position, means that we can begin to unpick some of this ideology and move students into new ways of working.
In trying to address these issues as reflected in the choice of design brief area and design solution, we unsuccessfully worked through a range of iterations. In our second iteration we tried allocating students blindly to different design areas. This resulted in students becoming uninspired and stuck in areas that they found challenging, and often resentment building for the students who had been 'lucky' enough to be allocated to WASH areas. In the third iteration, we asked student teams to pitch for their desired design area, and to present the most obvious solution. We then asked all the students to discard the presented solution and spend their time finding a better way to address the problem. This did result in some good innovative thinking, but students still clustered around the WASH area, and we had a number of versions of 'not-quite-water-filters'.
Finally we adopted the current method, where students do not form their teams or pick their design area until after a prolonged period of divergent thinking and conceptual design generation. The students fill design books with drawings, clippings and imaginings, with no care as to the structure or function of the idea. They then pick the best ideas that are most likely to translate to a practicable option and anonymously present them for peer review and allocation. This is detailed a little further in the next section as it is linked to our biggest educational innovation – merging the strands of study.

4.2 Merging strands of study

We have merged our four second year course options into a single course, with four learning strands. There have been two key benefits to this approach. As mentioned above, it can help students to break out of one pattern of thinking and to see their task in a new light. For the non-business oriented students, seeing the community as 'customers' as the business strand do has made them realize that they need to engage with them during the design process, and not impose their design on the community without any consideration or consultation. At a broader level, this introduces the second key benefit. This sharing of ideologies and approaches between the streams, has enabled us to develop a 'common core' of curriculum for these four courses, that introduces all these students to a variety of different ways of thinking about development, design and their own role as innovators.
The course is broadly structured as follows, with students in each strand working on aligned content that makes sharing ideas across the strands easy and beneficial:

- Weeks 1-5: introduction to sustainable human development and exploration of the community and design brief analysis – mixed strand student groups
- Weeks 6-10: conceptual design development – mixed strand student groups
- Weeks 11-15: technical specification/production of exhibits

- Weeks 16-20: preparation of implementation package and reflection on process

Each session begins with all students working together to discuss key concepts and share their progress so far. Students work in mixed groups for the first ten weeks, with students from each strand represented in each working group. This maximizes cross-fertilisation of ideas. At week ten, the students anonymously post five conceptual designs online for their strand, which are then voted on. The design groups which then pursue each idea in weeks 11-20 are made up of students from that course strand including the student that posted the idea, and other students that picked that idea as a priority choice. This means that when the students come together as a design team they already have a common focus that unites the team. This has effectively alleviated the issue of teams with very varied interests or ideas running into team working difficulty, and also the issue that we frequently encountered previously with some student groups remaining 'stuck' for the majority of the course with no good ideas to work with.

In summary, a student undertaking the Design for Sustainable Development strand might work through the following process.

1. Introduction to the idea of working in SHD using a deconstructed approach to critically consider the meaning of development, and how the discourse is dominated by notions of power and expertise
2. Engagement with a real-world case study in a sensitive and empathic manner, and discussion of the challenges of intersubjectivity in this problematic and contested field
3. Exploration of the selected community, taking time to generate a genuine understanding of the complex dynamics, needs and desires of the community using an adapted version of Soft Systems Methodology [7] to facilitate this; this phase represents the opening of a 'virtual dialogue' with the community and is supported in real terms by a moderated forum that allows the students to pose some questions to representatives of the community, but is largely down to the students empathically modelling the community's input; if successfully engaged with, the modelling techniques allows the students to identify opportunities for intervention within the community
4. With these opportunities in mind the students develop their design questions, which are interrogated using the SMART tool [10]
5. Conceptual design, where divergent thinking is explicitly encouraged
6. Peer review of conceptual designs
7. Refinement and technical specification
8. Creation of an implementation package that completes their 'dialogue' with the community

5 CONCLUSION

At Imperial College we have designed a cross-faculty engineering design module that runs alongside other design and SHD modules to allow free flow and sharing of ideas across traditional disciplinary and methodological boundaries. We are finding that over successive iterations of this course, modified by a process of action research, we are able to achieve deeper learning and engagement of the students with the ideals of the global dimension in engineering education. Furthermore, the students are taking the learning and impacts from this course back into their disciplinary study, where there are anecdotal reports of enhanced student performance.

Although we present here just one example of how the EWB Challenge may be embedded into undergraduate engineering curricula, the remit of the challenge allows institutions a large degree of flexibility in the way the Challenge is used and this variability is reflected in the national picture. As a mechanism for bringing the global dimension into engineering and technical curricula, the EWB Challenge is proving to be popular, with an increase in the number of universities and students participating on a year by year basis. The EWB Challenge is certainly effecting change to some extent in university curricula but to understand the degree to which this is occurring will take additional work that is scheduled for the 2015/16 academic year. In particular, EWB-UK is actively working to gather examples of best practice from a number of academics and institutional settings to better inform the integration of SHD into formal curricula and the development of the EWB Challenge itself. With additional resource in the forthcoming academic year we hope to be able to provide demonstrable evidence that the EWB Challenge is effecting change within university curricula. Indeed, the change in the UKSPEC in January 2014 [11] to include more of a focus on social context and conducting activities in an ethical way demonstrates engineering education moving towards values emphasised in the global dimension in engineering education.

Certainly at Imperial College, this learning opportunity is located as an optional module outside the core departmental and faculty teaching and although it may be counted towards the final degree award, it is not integrated into the standard curriculum for each student in any meaningful way. International recognition of this module, via a European Best Practice award from the Global Dimension in Engineering Education EU-funded project has been helpful in engaging the wider college community with the value of this course, and it will be interesting to see how the module continues to evolve over the next few years.

Clearly, this paper is based on anecdotal evidence gathered via action research in one institutional setting, with a relatively small student cohort. Further investigation of student attitudes to the global dimension in engineering design and the value of cross-disciplinary learning would be desirable.

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HOW TO INCORPORATE SUSTAINABLE DESIGN IN THE INTERNATIONAL EUROPEAN PROJECT SEMESTER PROGRAMME: INSIGHTS FROM PRACTICE

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ABSTRACT
Sustainable design is highly relevant for design and engineering education, as designers and engineers are the ones that shape the (future) world. They can support a move towards achieving sustainable transformations. This article focuses on an educational initiative that incorporates knowledge and insights on sustainable design with the skills and attitude needed for interdisciplinary and international collaboration in a context of problem based learning. The article describes the approach taken for integrating sustainable design in the European Project Semester Programme, and how the content of the course has supported the student projects. The article concludes with lessons learned and future opportunities for further integrating sustainable design in an interdisciplinary educational programme.

Keywords: Sustainable design education, interdisciplinary projects, international collaboration, problem based learning.

1 INTRODUCTION

Design and engineering education plays an important role in equipping its students with the necessary knowledge, insights, skills and attitudes that are needed in order to deal with the challenges the world faces. In order to tackle these challenges, graduates need to be able to work in interdisciplinary teams, often in an international context, and with a focus on current and future problems. Many of these challenges are related to sustainable development, such as climate change, resources, health issues, energy, etc. [1]. Sustainable design is one of the aspects that can support sustainable development and that is highly relevant for design and engineering education, as professional designers and engineers are the ones that do and will shape the (future) world, whereby they can support a move towards achieving sustainable transformations [2].

This article focuses on an educational initiative that incorporates knowledge and insights on sustainable design with the skills and attitude needed for interdisciplinary and international collaboration in a context of problem based learning. This context is the European Project Semester (EPS) Programme, an educational programme that assembles students from different backgrounds – both educational and geographical – interdisciplinary teams. The aim of the article is to offer insights on how sustainable design has been integrated in the EPS programme at the University of Antwerp in the Spring semesters of 2013 and 2014. Next to the approach taken to integrate sustainability in the programme, the paper describes how the content of the course has been applied by the students in their projects. The article goes also deeper into lessons learned from our experiences and suggests improvements and possibilities for further integrating sustainable design in the EPS programme.

2 THE EPS PROGRAMME

The EPS programme is an international educational programme that brings together students from different disciplines, backgrounds and nationalities during one semester. It offers the students a framework to practice cross-disciplinary product innovation and research in small teams [3]. Next to interdisciplinary project work, the students are challenged by courses taught by local and international guest lecturers. The projects always start with a specified problem statement and take place in a real-world environment in close cooperation with local industry. Since 2011, the University of Antwerp is one of the providers within Europe that offers the EPS programme to 25-30 of their own and exchange students, with a focus on the study programmes *product development, engineering, business studies, social work* and *teacher training*. Sustainable design has been added as one of the courses in the programme since 2013, thereby anticipating on the growing need for integrating sustainability in higher education. The early inclusion of the sustainable design course in the EPS programme at the University of Antwerp gave the flexibility to shape and adapt both the course and the programme to each other's needs and to arising opportunities, which strengthened the integration of sustainability within the complete semester.

3 SUSTAINABLE DESIGN IN THE EPS PROGRAMME

Higher education has the important task to prepare its graduates for the challenges the world faces. Many of these challenges are related to sustainable development. It is thus important to provide students with the insights and skills that can support societies to become more sustainable [4, 5]. The approach taken to integrate sustainable design in the EPS programme aims at supporting the students' competences for sustainable development, combining the four different aspects of competences: knowledge, insight, skills and attitude [4].

Competences for sustainable development can be divided into generic competences and field-specific professional competences. This first group of competences applies to everyone, regardless the area of study, and its goal is that students, - as future professionals, policy makers and consumers – are capable of reacting to changing situations and complex challenges in society such as globalisation, climate change, etc. [6]. Roorda presents six basic competences: responsibility, emotional intelligence, system-oriented, future-oriented, personal commitment and practical ability [7].

The manner in which the EPS programme is organised encourages and supports the students to develop most – if not all – of these generic competences for sustainable development. The interdisciplinary project work strengthens the development of different social and communicative skills that are needed to successfully collaborate in team, which increases emotional intelligence [3]. Moreover, the EPS programme strongly focuses on other aspects of collaborative and interdisciplinary work such as the division of responsibilities and the follow-up of personal commitment. Furthermore, all the projects the students work on focus on value creation for now and the future, and they require a systemic perspective from the students in order to bring together knowledge and skills from their different backgrounds and educational disciplines.

Supplementary to the generic competences, the course on sustainable design aims at supporting the development of specific professional competences by offering theoretical knowledge on environmental and social aspects of sustainable design, as well as it offers the opportunity to reflect on and apply this new knowledge in the semester projects. The sustainable design course is a course with a weight of 2 ECTS credits, led by two experienced sustainable design (guest) lecturers. The student group counts around 30-35 students (6-7 semester projects) each year. Teaching methods used in the course are interactive lectures, project work and a presentation of the results by the students. Most of the courses, work sessions and the presentations take place in a one week timeslot, which make it an intensive course for both lecturers and students. It preferably takes place in the concept stage of the EPS semester (between weeks 4-10 of the project), as this is the period in which the students have had enough time to get acquainted with the team, the project goals and its background, and they still have sufficient space and time to integrate sustainability within their projects.

Each of the elements of the sustainable design course within the EPS programme is explained in more detail within the following sections, thereby also indicating how it supports the different aspects of competences (knowledge, insight, skills and attitude).

3.1 Knowledge on environmental and socially sustainable design strategies

Theoretical knowledge on environmental and social aspects of sustainable design is offered in two parts of the course, each given by a different lecturer with her own specific expertise. The first part of the course introduces sustainable design, including the basics of life cycle thinking and the triple bottom line of sustainable development and design. It focuses on the environmental aspects of sustainable design and offers insights in ecodesign tools and strategies. The second part of the course targets social aspects of sustainable design. This includes an introduction on different sustainable design strategies such as design for sustainable behaviour, product service systems and system thinking, and sustainability in Do-It-Yourself (DIY). In total, the students have 6 hours of lectures in which this knowledge is presented to them in an interactive manner. However, in order to create sustainable value, it is equally important to be able to reflect on and apply the new knowledge in society, which is what the students do in the following part of the course.

3.2 Integration of sustainability in the EPS projects

In the practical part of the course, the student teams are asked to select and apply sustainable design strategies within their semester project. This means that the students need to reflect on the presented material and on the importance and relevance of the different strategies for sustainable design in the case of their specific project. The first aspect of the assignment for the students is to make a selection of strategies that are most relevant for their project, as well as to discuss and develop the argumentation behind their choice. No selection criteria are thereby given. The reasoning behind this reflective exercise is to let the students make the switch from gathering *knowledge* – based on the lectures - into getting *insight* on the different strategies for sustainable design, their relevance, possible impact, feasibility and their possible application in the context of their project.

Subsequently, the students are given the assignment to apply the selected strategy (or strategies) into their semester project. This step supports the development of the students' sustainable design *skills.* In practice, this means that the students work on different aspects and elements of one or some of the selected strategies, whereby each sustainable design strategy has its own specificity. The following overview indicates the main elements of each of the strategies the students need to consider.

Ecodesign strategy using the Life Cycle Design Strategies (LiDS) wheel and life cycle thinking. The students study the life cycle of their product and/or service within their project with the help of the LiDS wheel [8]. This tool indicates the different stages in the life cycle of a product/service with design strategies that fit each stage in a spin chart, visualising both the current and improved design solution. It supports the students in understanding the life cycle and in selecting relevant environmental strategies for their project, such as focusing on diminishing material use, selecting environmentally friendly materials, focus on the use stage of the product, extending the lifespan, etc.

Design for sustainable behaviour. The selection of this strategy implicates that the students make an analysis of the current behaviour of their target group. Main principles from social practice theory can support them by gaining these insights, such as the use of the elements material, skills and image that together can form a practice [9]. Based on the understanding of the current behaviour, the students need to define the wanted behaviour of their users in the context of their project. After doing this, the students can look for opportunities to influence the behaviour, using models on behavioural change and tools that present and support the selection of different principles for design for sustainable behaviour [10, 11]. During this work, the students also reflect on and apply main principles of design for sustainable behaviour, such as the distribution of control [10].

Product Service Systems (PSS). The selection of this strategy gives the students the opportunity to frame their project in a systemic context that brings together the physical product(s) and the service(s) they are developing. The students need to define the type of PSS (product, use or result oriented) that best represents their project [12], reflect on the stakeholders that are relevant for the PSS, define the PSS function and its energy, material and information flows, work out a PSS user scenario and develop a draft of the system with its different elements and flows [13]. Examples and a PSS template support the students in this process.

Do-It-Yourself (DIY). This strategy makes the students reflect on the accessibility of their project: how 'open' is it for others that are not part of the project team, but that can add sustainable value to the result? And how can the students facilitate this external knowledge and create the project in cooperation with users and other people that are involved and interested in their project? The selection of this strategy invites the students – in cooperation with the external project partner - to discuss the questions above and to discover if and how their project can become a platform for sustainable design that makes people share interest and knowledge and create a more sustainable world together [14, 15].

Applying the knowledge and learning the new skills of the presented sustainable design strategies also has an impact on the students' *attitude* towards sustainable design, however, this is not discussed further in this article. The following section presents the results of the student work in the EPS programme at the University of Antwerp in the spring semesters of 2013 and 2014.

4 SUSTAINABLE DESIGN IN THE PROJECT RESULTS

As a last part of the sustainable design course, the student teams present their work to the complete group. In this presentation, the students explain the selected sustainable design strategies in function of their semester project, the rationale behind that strategy choice, as well as how the group can and will integrate these strategies in their project. The presentation of the project results has a dual goal: to share the results with the complete group of EPS students so they can learn from each other and see how sustainable design strategies can be applied in different contexts, as well as to score the students on the work they delivered.

In the spring semester of 2013, six EPS projects were completed with the following topics: *home-made wind turbines, an interactive game to teach children about the history of music, an interactive cultural tour in a challenging intercultural area in the city of Antwerp, an interactive exposition about nuclear waste, a mobile snuggle space for children,* and *an e-board game that uses NFC technology*.

In the 2014 spring semester, five project covered the topics: *a follow-up of the interactive cultural tour in Antwerp, an interactive game for youngsters for the zoo of Antwerp, a hospital cocoon for new-born babies, a security awareness campaign in cooperation with a large international consultancy agency,* and *the development of a headset that can measure brain waves and brain activity* (more information on the projects on http://eps.ap.be/). As one can notice, there is a large variety on the project topics. This makes it interesting to see the selection of sustainable design strategies, but on the other hand, it also makes it difficult to generalise the results of the work done. However, reviewing the results from the courses in 2013 and 2014 gives interesting preliminary insights on how this course influences and supports the students, their projects and the broader EPS programme.

4.1 Selection of strategies

The selection process of relevant strategies for sustainable design for their project is an important aspect of the course, as it is there and then that the students need to understand what the different strategies entail, but also what the consequences of their choice are to their project. In order to make this reflection, a lot of freedom is given to the students, i.e. which selection criteria to use. Within the different groups and projects, and both in 2013 and 2014, it is clear that most project teams selected more than one strategy, and some teams selected all strategies to be relevant and to be applied in their project. This indicates that the sustainable design strategies presented to the students are considered relevant to their projects. Next to that, the argumentation behind the selected strategies is however rather limited, and sometimes even missing, although it is one of the questions asked in the student assignment for this course. The difficulty of selecting the most relevant strategy, together with the latter observation on a lack of argumentation of the students' choice, might indicate that the students reflect insufficiently on their choice and the consequences of that choice for their project and that this need for *insight* asks for more attention and emphasis in the course.

In 2013, the use of the LiDS wheel and design for sustainable behaviour were selected as the strategies to apply in the majority of the projects, whereas PSS and DIY were selected and applied in only two projects that year. A change in the time plan of the course in 2014, together with the limited applicability in the projects made us decide to remove DIY as a strategy in that edition of the course. PSS was kept as both the course lecturers and the EPS coordinator saw a high potential for applying this strategy in the projects for that year's EPS programme.

4.2 Application of strategies

An interesting observation on the application of the selected strategies in the semester projects is that the different groups selected some elements within each strategy that they consider interesting and applied these to their project. The two groups that selected PSS as a strategy in 2013 for example only defined the type of PSS that fits their project and a first, rough idea of how products and services can be combined in their project. Whereas design for sustainable behaviour as a strategy was selected in five projects in 2013, but four of the teams only used the 'design with intent' toolkit as a way of applying this strategy to their project. This user-friendly tool offers 101 inspiring patterns for influencing behaviour through design and can be used for brainstorming or as guidance for exploring the field of design for behavioural change [11]. One team made an analysis to understand, define and influence the current behaviour of their users. The restricted time of this course could explain the limited depth in which the students can elaborate their work and integrate the selected strategies in their project. However, a shift can be noticed in the results of 2014, in which several groups looked at the elements of the PSS and benefits for different stakeholders, as well as they made a draft of the PSS system and a functional analysis of the system. A similar path can be seen in the application of design for sustainable behaviour as a strategy, in which three of the groups that applied this strategy looked at understanding, defining and influencing behaviour. Two main changes in the course might offer an explanation for this improvement in the results: a) the limitation of strategies from four to three, which makes it easier for the students to focus and b) the introduction of a consultation and feedback moment per group, after the theoretical classes were given and before the students presented their work to the complete group.

The application of strategies for sustainable design has given new insights to students and the sustainability perspective has offered new opportunities and possibilities for the projects that the students did not consider previously. This is reflected in some of the reports of the groups, in which the students emphasize the added value of the sustainability perspective for their project, e.g. *'This course helped us improve our project by creating a surplus value (planet, people, profit). By doing this, our product becomes more interesting for both the company and the consumers'* (Scabbls – snuggle space team report).

5 LESSONS LEARNED AND FUTURE DIRECTIONS

A reflection on the sustainable design course and its results within the EPS programme of 2013 and 2014 offer some lessons learned and possible future directions. The aim of the sustainable design course is to offer the students theoretical knowledge on environmental and social aspects of sustainable design, as well as to offer the opportunity to apply this knowledge in the students' semester projects.

A first lesson learned comes from the results of the course that are shortly discussed in this article. They indicate that the strategies that are presented in class, such as environmental strategies assembled in the LiDS wheel, PSS and others, are highly relevant for the EPS students and the semester projects they work on. Indications are however also given on the limited depth of applying the sustainable design strategies in the project. This might result from strong time constraints of the course in general, but it might also be linked to the students' selection of several strategies, which implicates a higher work load within different areas of expertise. Moreover, the argumentation behind the strategy selection pinpoints a limited reflection of the students on their choice as well as on the consequences of that choice. More attention needs to be given to the students' insights in order to be able to make a good selection of sustainable design strategies. This could be done by guiding the selection process more by making the selection criteria more explicit. Selection can e.g. be based on the relevance of the strategy for the project, feasibility of applying it, possible impact of the strategy, available knowledge and skills in the team, etc.

A second lesson learned also applies to the limited depth of integrating the selected strategies as described above. A lot of new knowledge is presented to the students, after which they are expected to apply this new knowledge in a short time span. The results of the course indicate that bits and pieces of each selected strategy have been integrated in the different EPS projects and this new perspective is indicated by the students to strengthen the projects. However, it does not lead to a profound understanding of one or more of the strategies. What these insights offered us is to reflect on the necessity for the students of fully grasping one or more of the sustainable design strategies, or if it is more important to offer them an introduction to different opportunities on how sustainability can find access to their projects. A future direction could be to spread the course over time within the semester, in which the students first get the theoretical classes, and subsequently get some time to digest the new knowledge and to start applying it in their projects. A session some weeks later can provide the students with feedback on how they are integrating sustainability in their project, which can support the further integration of the selected sustainable design strategy into the project's progress.

A third lesson learned concerns the aim to support competences for sustainable design, including knowledge, insight, skills and attitude. Knowledge and skills are covered well within the course, and a stronger focus on insight and reflection from the students has been discussed previously. However, the attitude towards sustainable design from the students has been underexposed in this article. This can be explained due to a lack of available measurements on attitude. Assessment of the EPS semester programme combines grading on the project result, process assessment, peer reviews and reflections from the students, and grading on the supporting courses. Measuring the (change in) attitude towards sustainability from the students could be integrated in this assessment process, e.g. with a survey or as part of the reflective writing process.

A fourth and last lesson learned is related to the content of the projects. As described earlier, the projects cover a high variety of subjects. Some of these projects do have an environmental or sustainable focus, e.g. the home-made wind turbines, whereas other projects have other priorities, e.g. a security awareness campaign. The course aims at offering some interesting insights to all kinds of projects by including different sustainable design strategies, however there can still be variations in the potential and applicability of these strategies within the different projects. How to deal with this, especially in the scoring process, is an issue that needs further attention.

Although there are still improvements possible, we do believe that the sustainable design course within the EPS programme supports the development of sustainability competences of our students.

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USING ENGINEERING DESIGN TOOLS IN MULTIDISCIPLINARY DISTRIBUTED STUDENT TEAMS

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ABSTRACT
Collaborative design practice in distributed student teams is becoming more popular as technology makes it easier to communicate ideas with others that are geographically distant. However, a challenge for students is to use design tools which they are not familiar with. These design tools usually differ from each other and engineers may find it much more difficult to share their ideas. This could make the whole design process longer and less successful. Each year the *University of Malta*, *City University London* and *University of Strathclyde* organise a joint collaborative design project, involving engineering students with different disciplines and cultural backgrounds. In this paper, the patterns of use of design tools by students to collaborate with each other are investigated. Based on survey results of students, this paper proposes an approach which can be utilised by engineering students to enhance collaboration in multidisciplinary distributed design teams.

Keywords: Design collaboration, social media, collaborative design, student projects.

1 PROBLEM BACKGROUND

Information computer technology has facilitated the collaboration of different product development stakeholders located at different places around the globe. Collaboration in product development brings along a number of advantages such as sharing of expertise and improving the product performance metrics, particularly a reduction in the time-to-market. At the same time, such a collaboration poses a number of challenges as it typically involve people of different backgrounds, cultures and working practices. In addition, if the engineers select an inappropriate design tool, the outcome can be very disappointing, as the desired goals may not be reached [1]. Another challenge that usually arises in design teams is the way that the work is distributed amongst the designers. To distribute the workload in the most efficient way, the project manager or the team leader must have some previous experience and knowledge about team members. Unfortunately, this is not always achievable and thus a project may not be carried out in the most efficient way [2].

It is widely accepted amongst engineering lecturers and educators that collaborative team exercises or projects greatly encourage innovative ideas [3, 4]. Studies suggest that globalisation is progressing rapidly [3, 4] and hence it is highly beneficial for engineering students to take part in collaborative exercises [5]. These types of exercises and projects are becoming more popular and students are being introduced firsthand to design projects at an early stage [5].

The advantage of online communication technology was highlighted in previous studies. For instance, Wiki websites were created for each team of engineering students to create, edit and compile the project [6]. The students who took part in this project found the website very useful and relatively easy to use, indicating that engineering students can benefit from use of online technology to work together [6]. Engineering course projects also enhance the students' cognitive and problem solving ability, thus being better prepared for a dynamic design team with greater responsibility [6]. Systematic design engineering is used in some specific situations hence its applications are limited as it is a theory based on engineering design science [7]. In previous studies, models were created to aid the design engineering teaching stage by proposing guidelines that can be followed by the lecturers [8] but these did not deal with collaboration in engineering design in academia. Therefore to address this gap, the objective of this paper is to propose an approach which can be used in a dynamic design environment involving distributed teams of students.

2 BACKGROUND TO THE GLOBAL DESIGN EXERCISE

In a multidisciplinary design project organised by the University of Malta (UOM), City University London (CUL) and University of Strathclyde (UOS), distributed design groups were formed of a number of students from each of these universities. This eight-week project, known as the *Global Design Exercise* (GDE), takes place in the winter semester. The teams comprised two to three mechanical engineering students from UOM, two to three mechanical engineering students from CUL and four to six Product Design Engineering/ Global Innovation Management students from UOS. The participating students were from different educational levels, some were in their third year of their studies while others were in their fourth or fifth year. In addition, the nationality of the students varied and thus each team had a mixture of different mentalities, cultures and ideas. All students however, had taken study-units related to engineering design tools, engineering design methodologies and Computer-Aided Design. The students collaborated both synchronously and asynchronously for eight weeks, using a range of communication tools, in order to develop designs for an airplane tray table that would make it easier to eat a meal while at the same time increasing the functionality of the table tray. *Doodle* was the main tool used by the distributed student team members to schedule meetings. Students had the opportunity to get hands-on experience of collaborative design in engineering, as this project simulated a real design environment with weekly deadlines and two presentations (one on the progress made towards the fourth week and a final one on the design solution). This exercise posed a challenge because the students never worked together face-to-face as an entire team.

3 METHODOLOGY

After the students finished the GDE successfully, a survey was conducted to investigate the preferred methods of collaboration, in particular to use and complete a range of design tools. The aim of the survey was twofold; (i) to investigate the procedure used by the students to complete each of these tools (for instance, Figure 1 illustrates schematically one of the methods used by distributed team members to complete the Quality Function Deployment - QFD) (ii) to find out which online means were used by the students to utilise the particular design tool.

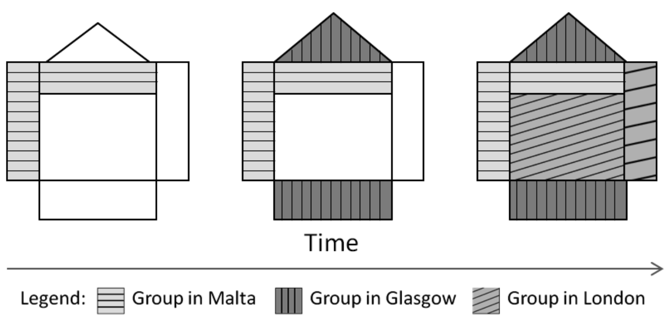

Figure 1. One of the methods used by some of the students to complete the QFD

The survey was structured in two sections reflecting the aforementioned objectives. The design tools considered were categorised to reflect the three main design activities as follows: (i) problem analysis tools covering QFD, product design specification (PDS) (ii) synthesis tools covering morphological chart (MC), brainstorming sessions (BS), Sketching (SK) and (iii) solution analysis and evaluation tools encompassing CAD, DFX, screen matrix (ScrM), scoring matrix (ScoM) and decision matrix (DM). Five key procedures that students follow to work on these tools were identified and included in the survey. These procedures are mentioned later on. The on-line means to complete these tools and which were considered in the survey comprised social media (e.g. *Facebook*), cloud computing (e.g. *Dropbox*), e-mails, *Whatsapp* and *Skype*. To investigate any significant relationship between the design tools and the procedures, a table was employed in the corresponding survey question. The same applies for the relationship between the design tools and the on-line communication means. Participants had to tick cells in these two tables. To ease accessibility by students located in three different countries, the survey was launched on-line. Fifteen GDE students, coming from different design teams at UOM, CUL and UOS, volunteered in the study.

4 RESULTS

The results of each question are analysed both analytically as well as statistically by performing a *Chi*-Square test for each set of tabulated data (a significance level of 0.05 was taken for all *Chi*-Square calculations). The results reveal that to complete QFD and the PDS, the majority of the students preferred to work on a design problem with their co-located team members, thus facilitating communication (69.23% and 53.33% respectively, see Table 1). To complete sketching and brainstorming, 64.29% and 50% respectively, opted to work together as a whole team simultaneously. It was also found out that 60% of the students preferred to have a single person from the team to work on the CAD model (see Table 1). When the *Chi-Square* test was carried out, the p-value obtained for the procedures used to complete problem analysis and problem synthesis tools was 0.716 and 0.161 respectively, hence no level of significance resulted. On the other hand, when the *Chi-Square* test was carried out for the results on the methods used to complete the solution analysis and evaluation tools, the p-value was found out to be 0.001. This means that there is a level of significance between the procedure used and the tool. The two most common and widely used procedures were those that involved either the local team working together or else the whole team working simultaneously. This reflects that a joint decision by all members of the distributed design teams was deemed important, in particular to select the final concept of the table.

Table 1. Results on procedures employed to complete the design tools

	One member in a team does all the work	Members in the same local team (e.g. Malta) work together simultaneously	In steps, one person at a time (same local team)	In steps, one person at a time from the distributed team (e.g. one from Malta, one from UK etc.)	Members in the distributed team work together simultaneously	Other
QFD	0%	69.23%	15.38%	7.69%	23.08%	0%
	0	9	2	1	3	0
PDS	0%	53.33%	6.67%	13.33%	33.33%	6.67%
	0	8	1	2	5	1
MC	7.14%	57.14%	21.43%	7.14%	14.29%	7.14%
	1	8	3	1	2	1
BS	0%	21.43%	21.43%	14.29%	64.29%	0%
	0	3	3	2	9	0
SK	7.14%	14.29%	21.43%	28.57%	50%	0%
	1	2	3	4	7	0
CAD	60%	26.67%	13.33%	6.67%	6.67%	0%
	9	4	2	1	1	0
DFX	8.33%	66.67%	16.67%	16.67%	8.33%	0%
	1	8	2	2	1	0
ScrM	0%	57.14%	0%	14.29%	50%	0%
	0	8	0	2	7	0
ScoM	0%	57.14%	0%	14.29%	42.86%	0%
	0	8	0	2	6	0
DM	7.14%	50%	0%	21.43%	50%	0%
	1	7	0	3	7	0

The *Chi-squared* test performed on the data depicted in Table 2, revealed that there is no significant relationship between the types of problem analysis tools and the online means employed to complete them (p-value = 0.383). In this case, the most common means of communication used were *Facebook* and *Skype*. The reason for this is attributed to the highly versatile nature of these online tools. By using the latter, students can convey their ideas better through gestures and improved way of conversation, both of which are an essential part of a design process [5]. *Facebook* is also a very dynamic social media tool, where each team in the design exercise formed a *Facebook* group and students could share their ideas there. It also facilitates messaging, as the participants could post an idea and receive feedback from the rest of the team. Instant messages are also a very good feature as they also cater for the fast upload of photos, hence if a sketch was done, a photo can be taken and uploaded on the *Facebook* group or sent as a message to the members in a matter of seconds. In fact, for design synthesis tools *Facebook* was used as well, but *Skype* resulted to be the most popular. For brainstorming 93.33% of the participants used *Skype* as the tool to communicate their ideas. *Dropbox* was also used significantly to complete the morphological chart and to store the sketches generated. Cloud storage was useful for design synthesis – for instance respondents highlighted that the original morphological chart can be uploaded and each team member can edit and add ideas to the same chart, instead of having multiple files. Regarding the solution analysis and evaluation tools, the use of *Facebook* and *Skype* was also very consistent. Similarly, the use of cloud storage proved to be very popular. The results of the *Chi*-Square test show that there is no level of significance between the use of design tools and the online means employed.

Table 2. Results on the on-line means used to complete the three categories of design tools

	Whatsapp	Facebook	Google Drive	Email	One Drive	Dropbox	Box	Skype	Other
QFD	14.29%	64.29%	42.86%	21.43%	0%	42.86%	14.29%	64.29%	7.14%
	2	9	6	3	0	6	2	9	1
PDS	20%	60%	33.33%	20%	6.67%	33.33%	20%	66.67%	0%
	3	9	5	3	1	5	3	10	0
MC	6.67%	40%	33.33%	13.33%	13.33%	40%	20%	66.67%	0%
	1	6	5	2	2	6	3	10	0
BS	26.67%	46.67%	13.33%	6.67%	6.67%	20%	6.67%	93.33%	6.67%
	4	7	2	1	1	3	1	14	1
SK	13.33%	53.33%	26.67%	13.33%	13.33%	40%	20%	46.67%	6.67%
	2	8	4	2	2	6	3	7	1
CAD	7.14%	42.86%	28.57%	7.14%	0%	28.57%	14.29%	35.71%	14.29%
	1	6	4	1	0	4	2	5	2
DFX	8.33%	50%	33.33%	16.67%	0%	50%	8.33%	50%	8.33%
	1	6	4	2	0	6	1	6	1
ScrM	0%	42.86%	50%	14.29%	7.14%	35.71%	21.43%	57.14%	0%
	0	6	7	2	1	5	3	8	0
ScoM	0%	42.86%	50%	21.43%	7.14%	35.71%	21.43%	42.86%	0%
	0	6	7	3	1	5	3	6	0
DM	7.14%	50%	50%	21.43%	7.14%	35.71%	14.29%	50%	0%
	1	7	7	3	1	5	2	7	0

From the data collected in Table 2, a bar chart was generated to pictorially illustrate the use of the most popular on-line means, namely *Facebook*, cloud computing (consisting of *Dropbox* and *Google Drive*) and *Skype*, during the different design activities. From Figure 2, it can be observed that the use of cloud computing increased sharply towards the last stages of the design process. This was expected as in the last design stages the number of design information generated (particularly CAD files) increases. Figure 2 also suggests that the use of *Facebook* and *Skype* was very consistent throughout the different design activities.

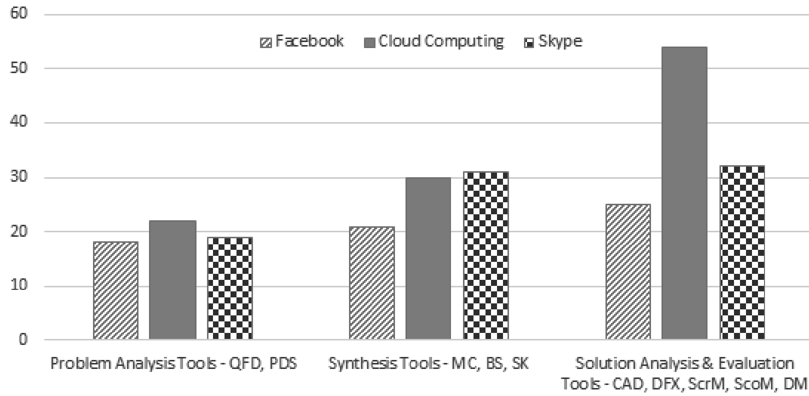

Figure 2. Most common on-line means used to complete different design tools

5 PROPOSED APPROACH

Based on the survey results obtained and preliminary qualitative feedback obtained by a focus group, made up of one CUL student and two UOM students, an approach was devised for distributed student team work (see Figure 3). The original model was improved by including *Skype* in all of the stages of the model, since problems that arise while tackling that particular task can be solved by meeting on a video call and thus clarify the issue. In addition, with respect to the original model, the meetings of the whole group were introduced at critical activities during the design process, particularly the brainstorming, sketching and compiling of the decision matrix. With reference to the model, it is recommended that during problem analysis each local team works independently on the QFD and PDS. *Facebook* and *Skype* are proposed to share information in this regard. At the end of the problem analysis activity a review meeting is held between the whole team members. This serves as a checkpoint for the team (e.g. in the case of the problem analysis to check that all the important design specifications are listed in the PDS). The same applies for the other two main design activities.

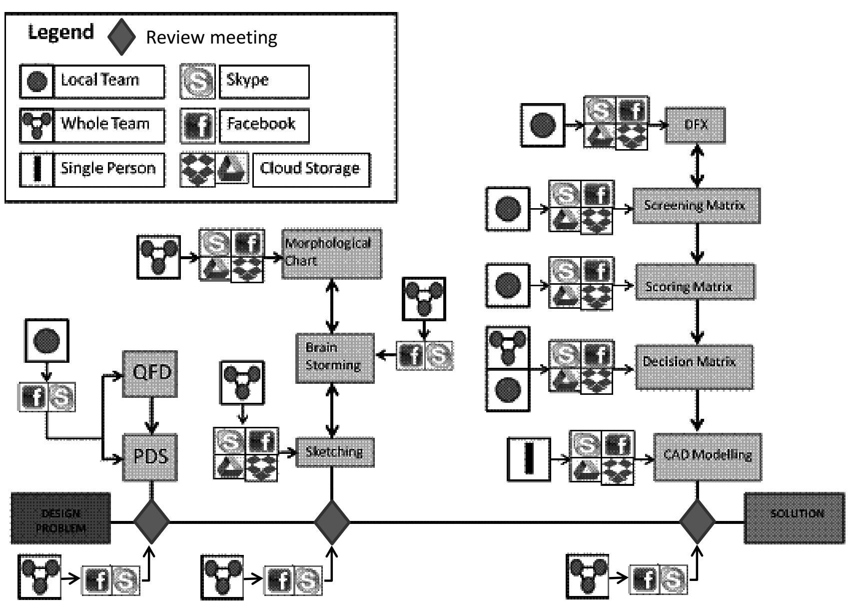

Figure 3. Proposed working approach for distributed teams of design students

The design synthesis activity is characterised by meetings held between members of the whole team, using *Skype* and *Facebook*. It must be mentioned that this model does not rule out asynchronous communication means such as e-mails. *Dropbox* and *Google Drive* are the suggested means to share information (e.g. sketches and morphological charts). In the design solution analysis and evaluation activity it is proposed that the DFX, screening matrix, scoring matrix and decision matrix are conducted primarily by local teams. It is only for the decision matrix that the whole team members are involved. In any case, the information generated can be shared by cloud computing for members of the whole team to access at any time. This shall lead to a faster consensus between all team members to select the final working principle, than if the whole team members had to meet using *Skype* to provide their collective input to fill in the other matrices.
The three focus group members were asked to assess the proposed approach by rating a number of statements using a 5-point Likert scale. Key findings were that students expressed a neutral opinion on the idea of using this model in future projects and on its effectiveness (in both cases an identical mean rating score of 3.4 was obtained). The main reason attributed to this lies in the fact that the opinion expressed is based on the students' impressions rather than on hands-on experience in using the model.

6 CONCLUSIONS

This paper has investigated the patterns in the use of design tools by students in engineering design to collaborate with each other. The main contribution of this paper is to propose tools for distributed design as shown in Figure 3. The proposed approach could provide a roadmap for design educators to guide engineering design students on how to best use the design tools together with on-line tools at different stages in a distributed design context. Such an approach would facilitate collaborative design exercises between students. However, future work is required to test the validity of the approach by using control and experimental groups and test the efficiency of the approach, particularly in terms of the number of ideas generated between the distributed team members in a stipulated timeframe and the time taken to decide on the optimal design solution.

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WHY INTERNATIONALISATION OF DESIGN EDUCATION BENEFITS UK STUDENTS

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ABSTRACT
Chinese design students are drawn to the UK for a variety of reasons, not least of which is a consequent increase in their worth in a post-graduation employment market. By undertaking a UK design education Chinese and other international students can demonstrate to potential employers a willingness to undertake difficult challenges allied with a capacity to collaborate productively in a transcultural context. Such prime qualities command a premium in a competitive global employment market. Notwithstanding the benefits that visiting international students gain from studying in the UK, such rewards are not confined solely to visiting international students. At Coventry University, undergraduate design students have the opportunity to experience a culturally disruptive experience by way of a ten-week studentship at Chinese institutions with which the University has established collaborative relationships. The skills they acquire are globally relevant and help open the door to opportunities not available to those UK students who choose to adopt a more parochial approach to their design learning journey. Through case study, this paper explores the advantages that UK design students can also gain from being exposed to transcultural collaborative learning experiences among Chinese students both in the UK and within Chinese higher design educational institutions. It also offers insights that challenge Western preconceptions of the stereotypical Chinese learner and suggests that unquestioning adherence to cultural expectations risks missed pedagogical opportunities that can benefit UK and international students alike.

Keywords: Internationalisation, transcultural, pedagogy, design education, China, cultural dimensions, Hofstede.

1 INTRODUCTION

This paper argues that exposing UK design students to an internationalised dimension as part of their learning experience confers significant advantages, not least when faced with the imperative of finding meaningful employment. This theme is set against Hofstede's claims for the influence of cultural dimensions that he asserts manifest themselves widely, not least in the learning environment where cultural differences carry pedagogical implications [3]. A stereotype emerges of Chinese students studying in the West that has its roots in Hall's expositions on cultural difference [2] and in Hofstede's quantitative methodologies that seek to categorise cultural differences via combinations of distinct national cultural dimensions [3]. Thus Chinese students are marked out as passive learners who are reluctant to speak out in teaching sessions; who have a low toleration of uncertainty; who, in their dealings with teachers expect to work within a high power-distance relationship; and who are inclined towards collectivist rather than individualist action. While these cultural dimensions are held to be generally homogenous within any given nation by proponents of Hofstede's view, this author is particularly interested in exploring the idea that perhaps designers and other creatives - possibly because of an innate potential for and receptivity to unconventional and iconoclastic ways of thinking - are less likely to conform to neat culturally stereotyped behaviour even if a wider overarching cultural stereotype appears valid.

2 METHODOLOGY

Notwithstanding Roworth-Stokes warning, "that the primary advantage of the case study, its ability to reveal insight into 'real-life' contemporary phenomena (the here and now) set against critical incidents, happenings or events over time (cause and effect), could be undermined by a lack of methodological rigor and sound empiricism in design research" [10], this paper uses case study to try to critically evaluate the manifestation and influence of Hofstede's dimensions of national culture in the context of UK and Chinese design students in a transcultural learning environment. By making qualitative comparisons across the case studies under discussion this paper sceptically challenges the rigidity of Hofstede's quantitatively derived assertions to suggest that the manifestations of cultural dimensions are more nuanced than is generally held to be the case. The first case study outlines the experience of UK product design undergraduates who spend a 10-week semester studying at a university in Zhejiang province, P.R.C. The second revolves around resident postgraduate industrial design students studying at Coventry University. Both case studies are explored against a background of cultural stereotype and compare actual observed phenomena with Hofstede's expectations to highlight areas of difference. Additionally, a central argument of this paper is that for UK students, the exposure to transcultural learning experiences gained while studying and working among international students brings benefits, opportunities and creative stimuli that simply aren't present in a more parochial learning context. The paper hopes to demonstrate that there are pedagogical lessons to be gained by not being quick to attribute student behaviour and learning attitudes to assumed culturally-rooted phenomena.

3 BACKGROUND

The background to this paper is the situation at Coventry University's School of Art and Design (CSAD) that has seen, since 2004, a continuing strategic expansion in its internationalised student recruitment efforts, most especially in its recruitment of Chinese students. A key component in the increasing internationalisation of the University's design programmes has been the establishment of formal relationships between Chinese higher education institutions and Coventry University faculties. Of these, Zhejiang University of Media and Communication (ZUMC) has a research and pedagogical relationship that is bound up, in the context of this paper, with the undergraduate Product Design course.

4 CASE STUDY 1 - UNDERGRADUATE INTERNATIONALISATION

Since 2011, CSAD has been sending around a dozen or so UK product design students (approximately 25% of the eligible pool of candidates) to the Tongxiang campus of ZUMC each summer semester, and since its inception approximately 45 have made the trip. To help the UK students cope with and adjust to the disruptive cultural jolt they are assigned a number of Chinese volunteer students on design courses at Tongxiang who are tasked with helping to familiarise the UK students and ease their path into what is undeniably a novel and challenging situation. It rapidly becomes clear to the UK students themselves just how vital these dedicated and remarkably conscientious volunteer students are to the success of the mission. The role of the student volunteers is wide-ranging with significant responsibilities; serving as translators, guides, fixers and coordinators. In a learning context, these volunteers and other Chinese students engage in joint design projects alongside the UK students. Pro-active, gregarious, openly curious and very keen to initiate conversation with both UK students and accompanying UK tutors alike, these Chinese students seem to be the very antithesis of Hofstede's introverted, passive and hierarchically subservient cultural stereotypes. If Western students are often characterised [2],[3] by an inherent willingness to contribute and speak out, by a higher toleration of uncertainty, by their willingness to act in the absence of full information, by their preference for individual rather than collectivist action and by their expectations of low power-distance relationships within institutional structures, then from this author's own direct observations it can only be said that the Z

That said, within the classroom or during formal meetings that involved senior members of staff or high ranking visitors, the social and behavioural dynamic did alter somewhat, as observed by the author at first hand. Certainly, the Chinese students adopted more passive, respectful attitudes and were less willing to interrupt superiors than at other times, but the really noticeable phenomenon was that when the UK students were similarly exposed to these experiences, especially early on in their programme, they too became tangibly introverted and decidedly uncomfortable at times - especially so when discussions were in Mandarin with only occasional and minimal English translation. In short, the UK students adopted a collectivist behavioural attitude that more or less precisely mirrored the dimensions cited by Hofstede as being typically Chinese. The outgoing and ebullient characteristics that might normally characterise them in less taxing settings had all but disappeared. Clearly, they had not suddenly undergone some sort of spontaneous cultural paradigmatic transformation; the observed reality was far more pragmatic. Because of the considerable barriers of language and communication combined with a lack of a familiarity of cultural, behavioural and social norms in these sorts of situations, the students' instinctive coping mechanism was simply to remain silent and passive. Since they couldn't easily understand what was happening they adopted an attitude of silence and invisibility until the meeting was finished, after which they immediately engaged in animated discussion with each other and with the English speaking Chinese students to try to gain an understanding of what had been said and what was expected of them. The similarity in behaviour of the UK students under these circumstances was uncannily like the behaviour that this author has witnessed first-hand of Chinese students in UK classrooms under similar conditions - and probably, to a degree, for the same reasons. Clearly, then, assumptions that when Chinese students are exhibiting this sort of behaviour in learning environments in the UK they are simply conforming to an innate cultural stereotype risks a blindness to other underlying factors, which, as can be seen from this real-life example, may be far more pragmatic and somewhat less exotic.

Further, it was apparent to this author that the Chinese volunteers are in possession of a degree of self-motivated initiative and developmental maturity that, frankly, the author has found to be generally rather uncommon among UK student cohorts. Indeed, this was a perception that came to be acknowledged by some of UK students themselves who came to view Chinese students *within their own environment* as highly tolerant of uncertainty, fully prepared to take risk, happy to challenge within a power distance relationship and more than capable of operating at an individualist rather than a collectivist level. In discussions with the Coventry students after their return to the UK, it became apparent that a normalised former laissez-faire attitude towards international students at Coventry University had undergone something of a sea change. As one later articulated, "The willingness to support and assist myself and other UK students shown by the Chinese students has helped me re-evaluate the often lacklustre approach I once had towards international students…I developed a lot of respect for the Chinese students, and their eagerness to learn, interact with and conjure up friendships with foreign students is an ethos that I have taken on board." (Source anonymised).

Other students expressed similar views. "After studying in China, I feel I've learnt a great deal about social differences between Chinese and Western culture. I think this helps me to be more tolerant of other cultures in different scenarios and to also communicate better with students from other cultures now I'm back in my home country." (Source anonymised)

4.1 Internationalisation and Mutual Benefits

One of the key tenets around which the initial establishment of the CU-ZUMC relationship was founded was the idea that visiting UK design students would gain practical exposure to working with live clients in China who would set commercially realistic briefs that could potentially see their concepts put into production. The benefits of this arrangement are designed to work at many levels; ZUMC gains valuable experience and insight into how the design processes are taught and delivered under a Western pedagogical paradigm, and local industrial companies have access to a pool of talented Western designers and can directly benefit from any design outcomes they feel are of value to them. In the words of Andrew Beck, CSAD's International Partnership Manager, "Working together, faculty from both universities will work with local industry with the ambition of moving from 'Made in China' to 'Designed in China'…the joint research centre offers countless opportunities for students and junior faculty to undertake research in design, in design curriculum innovation, and in the management of design education and design processes."

At home product design students gain professional experience through internships and by working with live clients on collaborative briefs, it is of a magnitude more challenging for UK students to find themselves in high-profile briefings comprising representatives of industry, local government and senior university officials and which is conducted entirely almost entirely in Mandarin within an overarching alien cultural environment. It is this exposure to novel, challenging and socially uncertain factors that serves to subsequently strengthen the UK students' intellectual, social, emotional and creative capabilities. If at first UK students are somewhat inhibited and introverted, it soon becomes a matter of functional necessity that they learn fast about developing strategies for coping and thriving under these testing conditions.

Generally, within the first week, two briefs are issued. The first is usually in collaboration with a local manufacturing company and typically involves designing or redesigning an industrial product of some sort. Past examples have included a domestic heating controller, domestic cleaning products and interior and exterior lighting aimed at both the home and international market. There is the potential for a successful design to be put into production, which is a major incentives to the UK students. Other projects having involved designing a high-value crafts-based souvenir intended to promote West Lake, an area of outstanding natural beauty to the west of Hangzhou, and a project in collaboration with a theatre production company. For the 2015 visit, a new brief was written by this author with the strategic aim that both Chinese and UK students would engage in a project designed to elicit a cross-cultural response and which would involve an effort to decode artefacts to discern culturally derived aesthetic and functional affordances.

Over the course of the following ten weeks or so, the Chinese and UK students work together on both projects and rapidly became self-reliant and pro-active in negotiating difficulties and overcoming barriers, becoming tolerant of uncertainty in the process and developing something of a collaborative, collectivist mindset in the process. Interim presentations and feedback ensure that the assignments are kept on track. The final week sees an exhibition of the students' work attended by local dignitaries alongside the ZUMC team and representatives of the contributing client companies. The learning distance that the students have travelled is significant and is not lost on the students themselves:

"Even though the language barrier may have been a slight issue, we managed to communicate professionally through our designs with the help of translators and students who were willing to help us with any issue we had… The international experience has given me insight into different working methods and in addition I have developed new skills within the design process, it has given me the confidence to make decisions which could impact on the design outcome." (Source anonymised)

Other students who've commented on their experience were more directly focused on how it would contribute to their own future employability, especially in a global context:

"I believe my experience in China will greatly benefit my postgraduation employment prospects. I feel I have successfully shown to any perspective employer that I am capable of being removed from my comfort zone (into a particularly different environment from any other) and still perform to a professional standard and even to excel and surpass expectations of multiple demanding international clients; despite adversity in the form of communication barriers and sometimes opposing understandings of culture and society."

5 CASE STUDY 2 - POSTGRADUATE INTERNATIONALISATION

The MSc Industrial Product Design and MSc Design & Transport courses at Coventry University attract an overwhelmingly-international student cohort, the majority of whom are Chinese. Within the learning spaces, the language of discourse is English. While some aspects of Hofstede's national cultural dimensions appear to be valid and are confirmed to an extent by the author's own experiences with working with Chinese students, the following case study demonstrates that there are nuanced aspects to these dimensions that suggest that such apparent manifestations of innate cultural difference may in fact be more accurately attributed to situational factors rather than deeply engrained, inviolate national traits. The second case study revolves around a projects that the MSc students undertake, which is a live brief set by senior R&D engineers from Ricardo, a world-leading engineering technology organization. Delivered as a group project, five teams comprising a mix of nationalities were set a brief in 2014 to design an innovative, energy efficient excavator that was to employ novel working principles. In apparent confirmation of cultural stereotype, all teams elected the more overtly outgoing Europeans as team leaders while Chinese students tended to be reluctant to volunteer for roles, choosing to accept allocated tasks based on other team members' evaluation of their skills and capabilities. In all formal project presentations it was universally the case for each team that the main spokesperson was a either a UK or a European representative while, consistently, Chinese team members spoke only in response to direct questioning on some aspect of the project that they were responsible for. Within the academic framework of the project, on the face of it, it appeared that Hofstede's categorised cultural dimensions were being accurately reflected in the team makeup and project implementation. Ultimately, two concepts were felt to be particularly strong; one called Pangea, the other, Hercules, and of these the Hercules concept was judged the final winner (Figure 1). Yet it was what happened after the completion of the project that helped to illustrate to this author how assumed preconceptions about cultural stereotype can be radically overturned if the social dynamic is propitious. And with this realization has come a considered pedagogical reappraisal of the supposed influence of cultural difference on the teaching and learning experience.

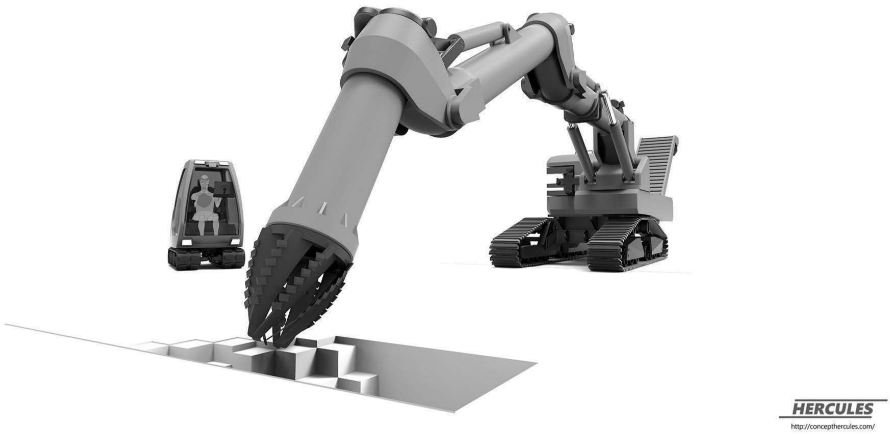

Figure 1. Hercules Excavator. Winner of the 2014 Red Dot Best of Best Concept Award (Source: Apostolos Papamathaiakis)

5.1 Transcultural Collaboration Brings Competition Success

Shortly after the project itself had formally ended, one of the Chinese students - under his own initiative and based on past experience - proposed to his fellow Pangea team mates that they enter their concept into the forthcoming Red Dot design competition. During the original project, he had not volunteered for a team leadership role, choosing instead to be responsible for delivering the CAD element. Yet outside of the original academic context of the brief and now operating within his own independent sphere free of academic oversight, he became the central driving force for the team. He was assertive in organising the team effort to deliver an entry against a severe deadline. Under this new team configuration, the UK and European students assumed less high-profile roles such as copy writing, proof checking and so forth and they reported to the Chinese student in his new role of de facto team leader. In the event, both the Pangea team and the Hercules team entered the Red Dot competition. The Hercules team went on to win the Best of Best Concept Award [7] with the Pangea concept winning the Best Concept Award in the Construction category [8].

In pedagogical terms, the dynamic, assertive and gregarious behaviour of the Chinese student during the Red Dot competition effort could not have been more in contrast to the behaviour he'd exhibited only weeks previously during the formal academic stage of the project. Upon reflection it has become clear that the innate potential for this behaviour had already been signalled via the adaptable and self-motivated Chinese volunteer students at ZUMC, Tongxiang. What both circumstances had shown was that outside of the academic learning space - a space in which behaviour, social decorum and cultural convention are formally encoded among Chinese learners who learn within a Confucian Heritage Culture system [9], [11] - these students, when freed from these codified behavioural expectations, are every bit as capable of free-thinking, self-initiated and gregarious engagement in collaborative contexts as their Western counterparts are usually held to be. But at a pragmatic level, it seems that the Chinese students' inhibitions in formal class settings may well be as much about an underlying lack of confidence in their language skills and a reluctance to have this exposed as anything more complex. In other words, the sharply contrasting attitudes of the same Chinese students operating on precisely the same project but under differing academic and social dynamics powerfully suggest that cultural behaviour imperatives are not as deeply engrained as Hofstede et al might claim.

6 CONCLUSION

Cultural difference is relevant and does exist. What this paper argues is that its manifestation may often be masked by other factors that may be largely pragmatic or socially contingent. Such factors can be as applicable to native UK students as to those from other cultures. Case study examples appear to challenge the rigidity of Hofstede national cultural dimensions on the basis that it is too blunt an instrument to be pedagogically reliable. Further, work by Gieves and Clark [5] which uses Hofestede's quantitative methodology and data only to come to somewhat contra positions, and that of Chinese academics Cheng & Guan et al [4] imply the need for caution in blindly assuming that all apparent attitudinal differences among nationally diverse students within the classroom are inevitably culturally originated. What this paper does assert - based on direct feedback from UK students themselves - is that those students who choose to expose themselves to transcultural experiences will emerge enriched and developmentally transformed to their wider benefit. The final word goes to Ricardo's Dr. Shuttlewood: "Academic ability is one thing, but the most important is the ability to problem-solve via processes to the end-solution; through communication skills, organisational skills and skills obtained through multicultural team working." And as the sole English student representative on the Pangea team later commented, "Had it not been for the Chinese students it would never even have crossed my mind to have done something like enter the Red Dot competition. Working with international students has shown me that you can see things from a different perspective; see things differently." (Source anonymised) .

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Chapter 3

Learning Environments

DESIGNLAB, MAKING SPACE FOR DOING DESIGN AS A PROCESS

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ABSTRACT
The University of Twente has developed the DesignLab initiative to feed the "high tech, human touch" mission of the organisation. The combination of high tech and human touch was made one of the spearheads of the future, in order to bank on the universities unique position as a 'dual-core university' with both a strong science and engineering faculty on the one hand and a social sciences faculty at the other. This DesignLab has the mission to integrate the expertise of both academic kernels in "science2design4society", which means that design knowledge is used to make new technologies available for users and that, together with the latest insights in humanities and business, these are used to tackle problems in contemporary society. To make this happen, the DesignLab needed a dedicated space for doing design in multidisciplinary teams. Because a lot of the prospective users of the lab would not be trained as a designer, it was decided that the actual space of the lab should support the design process. The space that was developed and implemented was therefore not only furnished for the desired design activities, but also structured according the desired design process.
It is not yet evidenced that the space actually contributes to a more designerly way of working, the users are however very positive and the design process metaphor proved to be very helpful to build a shared vision within all the stakeholders involved in the DesignLab project.

Keywords: Multidisciplinary design, design space, design environment, human-technology relations, design curriculum.

1 INTRODUCTION

In accordance to the strategic positioning of the University of Twente as "High-Tech, Human Touch", the organisation has set out design as one of the central themes in the development of our institute. Where design is meant to be an integrator of the two kernels of our university. At the one hand the technological advances, researched and created in our technology oriented departments, and on the other hand insights in contemporary developments of society, as researched by our department of Behavioural, Management and Social Sciences. To address this integration challenge, a plan was formed to make a central platform for "science2design4society". The latter means that the initiative is dedicated to introduce specific teaching and research teams that are focused on creating a creative culture, "where scientific results from nano-, bio-, robo-, cogno- and info- technology are allowed to collide and to connect to real world challenges that people are facing today" [1].
To make this happen, a special place was needed to cater this; a place for innovation and inspiration, where every student and researcher at the University can go to seek and drive application of their work, and where industry, government and NGO's can gather to explore options to tackle the challenges they face, and where citizens can participate to actively shape their future. In short, the university wants to establish a situation where 'doing design' will be an accelerator for making technology available for people [2]. This paper is about the design and realisation of this place, which was eventually called the DesignLab.
The paper describes the theoretical background of the High-Tech, Human Touch perspective on design, and will show the process-concept and the implemented lay-out of the DesignLab in more detail.

2 HIGH TECH, HUMAN TOUCH

High tech, human touch means that technology cannot be understand on its own. A technology is not valuable when it is not made applicable for users. Technology can of course be valuable in an indirect manner, like photovoltaic technology that produces sustainable energy that can be used for electricity supply. We believe however that technology has more meaning for the people when it is directly used in applications that appear in the direct use context. For instance in charging stations for electric vehicles or systems for lighting public spaces (Figure 1). Design and design engineering play a major role in this transformation process from mere technology into a product that can be used [3]. To do this right (which means that the technology is efficiently used *and* the product fits to the prospective users and use context), both technology and user should be understood. That is why our university wants to bring together engineers and technologists with psychologists and philosophers of technology [4]. And that is also why we have dedicated a large deal of our design curriculum for the analysis and design of human technology relations [2, 5], including the impact on user and society [6].

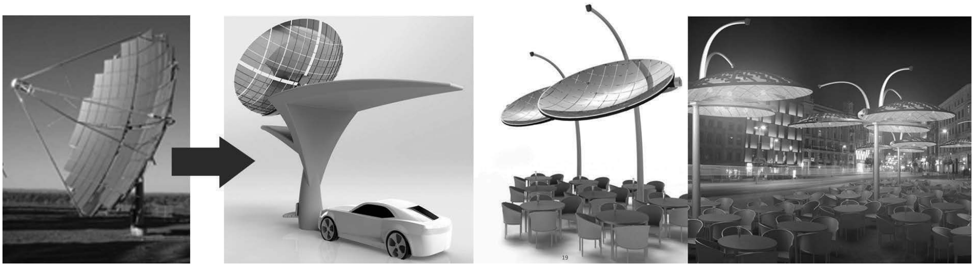

Figure 1. High tech, Human touch; a technology (left) is only meaningful to people when it is transformed into a usable product. Like for instance a charging station (by Jorien Bootsveld & Katja Schuitemaker) or sustainable parasols (by Ivar Kamies & Kyan Kuiper)

3 DESIGN CONCEPT

One of the key concepts of the science2design4society strategy is multidisciplinarity, where real world problems are addressed through many projects involving researchers, students, stakeholders, users, partners and experts. In short, this means that there will be a lot of people attending the DesignLab that have little experience with design as such. In this respect we believe that our 'place for doing design', should not only support mere cooperation, but should also support design as a process [7, 8].

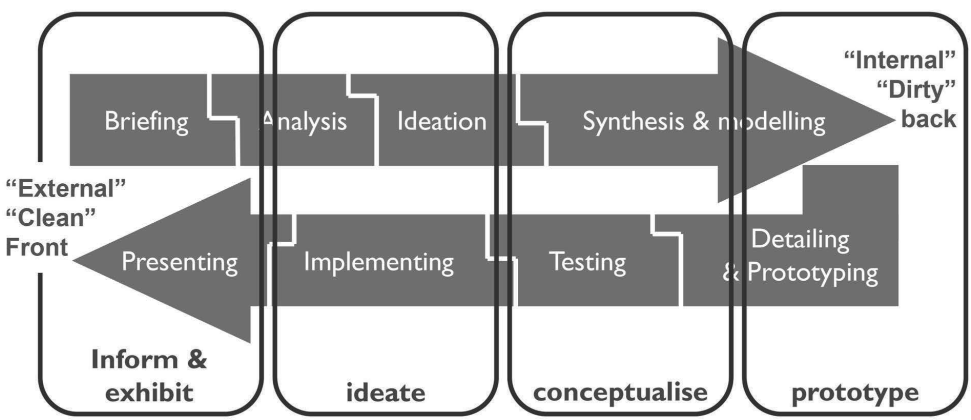

Figure 2. Mapping of the DesignLab space on the 'generic' design process. The design problem literally goes back and forth through the lab

The solution for this design support is implemented in a space that is physically structured as a design process. Several design processes were investigated and eventually integrated. In the technology oriented part of our community the linear stage processes are the most common, like the design processes of Pahl & Beitz and Roozenburg & Eekels [9]. In the people oriented disciplines however, circular and reflective processes are used more often and these are also adopted in for instance the Delft Innovation Method [10] and the Eindhoven reflective transformative design process [11]. We combined these two basic principles also earlier in our own design process for Creative Technology [12], which was developed for the integration of the technology- and human centred perspectives on design. These insights resulted for the DesignLab in a generic design process roughly divided in five design phases; Briefing and Analysis, Ideation, Conceptualising, Prototyping, and Exhibiting/ Communicating. These phases should be closely linked then, to allow for circular iteration and reflection. Figure 2 shows the mapping of the specific areas on the design process. The idea is that a design problem goes back and forth through the entire space: from the briefing at the entrance all the way to the workshops for prototyping and back to the exhibition area in the front for presenting the solution to the outside world.

Figure 3. Three main activities in the design process: working together in teams during ideation and conception (left); prototyping (mid) and exhibiting (right)

Building on the structure of the design process, a specific floor plan was made where every design phase has its own space, dedicated to the activities that characterize that phase (Figure 3). Most space is dedicated for working in teams, however following the design process metaphor of figure 2, there are also workshops for prototyping and a central exhibition area for showing results. As argued before, all spaces are closely together to allow for quick circular iteration, which is considered mandatory for a good design process.

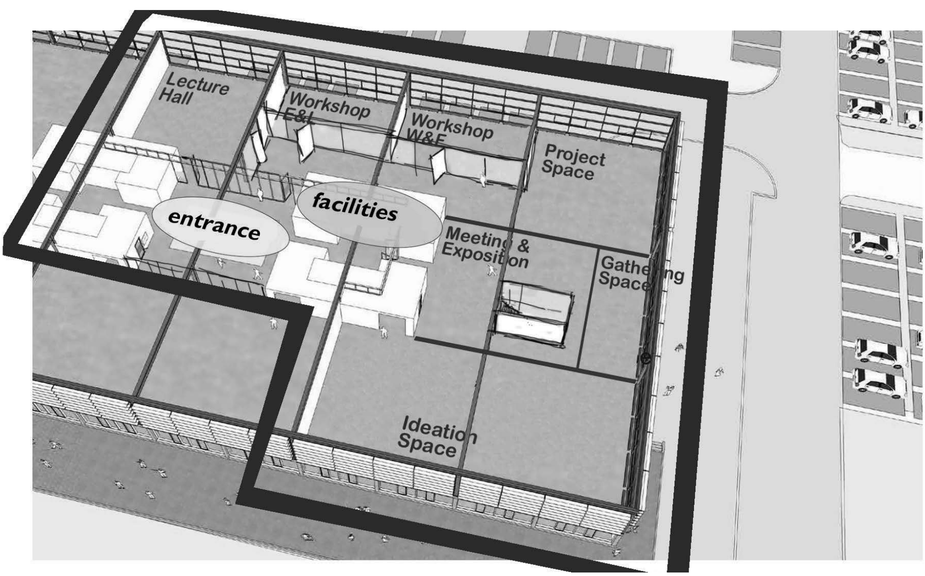

Figure 4. Overview of the layout of the lab in the selected building area

The idea of making the space like a design process was then implemented and illustrated in a master plan that served as input for the conversion of the building and the design of the interior. The actual building area that was reserved for the realisation of the DesignLab did not have a rectangular floorplan, so in the end the areas were grouped around the entrance instead of in a row (Figure 4 & 5).

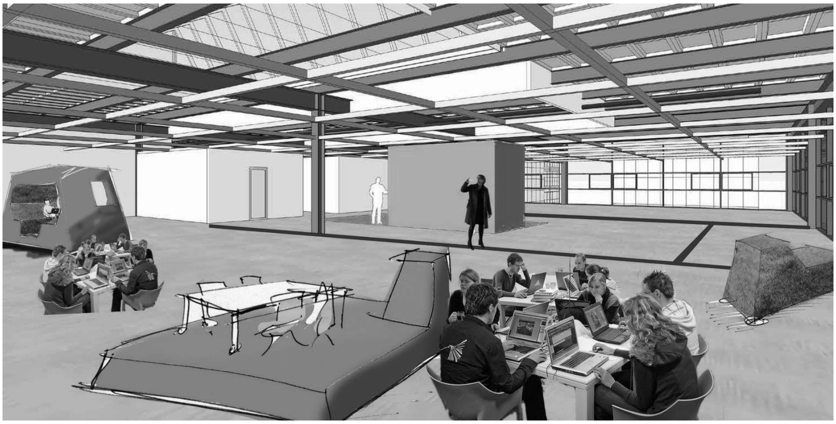

Figure 5. Impression of the DesignLab interior concept from the master plan

4 IMPLEMENTATION AND CO-DESIGN

Leurs et al. showed that the physical space for doing design has huge effect on the performance and self-confidence of design students [13]. To cater to the needs of the prospective users of the DesignLab, a team of students from Industrial Design Engineering was asked to develop the master plan into an inspiring environment. The students came up with an overarching design style called 'low-poly' and a set of dedicated design furniture objects (besides the obvious bar and lounge corner). The low-poly style is widely known from the tessellation of CAD files for rapid prototyping and is commonly used as a style that stands somewhere in the middle between nature and technology in a lot of illustrations. The style therefore fits both to the visual world of the students as to the high tech, human touch theme of the DesignLab mission. The special furniture objects in low-poly style were then mixed with standard project tables, whiteboards and chairs to make a complete interior. The designed furniture objects included a 'design-island' (in analogy with a cooking island) for doing design work in a group, a little 'house' to work individually and concentrated, and a pitch module with integrated stand for doing on-site presentations. The special furniture was constructed by a bigger team of students. To save costs of course and also to raise a sense of ownership for the DesignLab within the student community.

5 SPACE

After the implementation the result is an open studio-like space with a bright atmosphere, where students and staff can easily switch between different tasks. The openness of the space allows for easy adaptation to the specific needs of the moment and also stimulates community building and cooperation. Specific signing was developed to guide users of the DesignLab through the area and therefore also through the design process. To remind every visitor of the purpose of the DesignLab - eg doing design as a process - the design stages are also installed at the entrance (Figure 6, right).

Figure 6. Students doing project work in the finished DesignLab (left), one of the low-poly designs furnishing the lab (mid), and the signage of the design process at the entrance

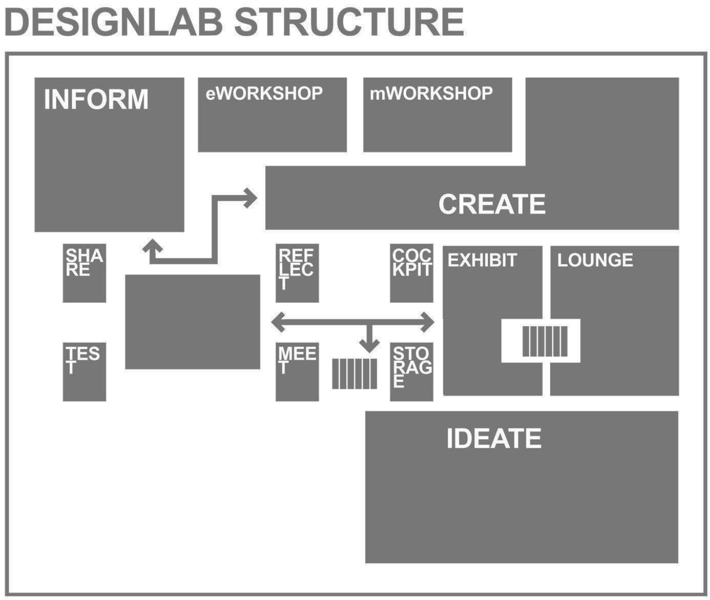

Figure 7. The structure of the DesignLab, according to the eventual implementation. The entire space is approximately 40 by 50 meter

6 DISCUSSION

The DesignLab works for the planned activities like lectures, symposia, research meetings and presentation of project results. These are however incidental activities, whereas the lab was meant to do entire multidisciplinary projects with a lot of stakeholders from the beginning (briefing in the 'Inform') to the end (presentation in the 'Exhibit') (Figure 7). Because research projects are mostly temporarily financed, based on the effectuation of proposals, these type of science2design4society projects that are dedicated for the lab still have to start off

Students have to find their way to the lab though for their design project work, thanks to the participation in the building stage. The users of the DesignLab at this time are mostly master students from Industrial Design Engineering and Human Computer Interaction, who are used to do design work from their bachelor. It is therefore hard to say whether the design process layout of the lab really contributes to the execution of projects in a more designerly manner (e.g. with a clear structuring of the project, including a separate ideation phase and several iterations). The users are however very positive about the open atmosphere of the lab, the possibilities to tweak the interior to their needs, and the fact that all the facilities are close to each other.

7 CONCLUSION

The process metaphor for the layout of a multidisciplinary design lab space has been successfully implemented. It is however not yet evidenced that the layout actually contributes to a more designerly way of working. The idea of making the space support the design process was at the other hand very valuable as a guide during the development of the DesignLab. Especially in creating a shared vision within all the stakeholders that were involved, not in the least because a lot of these stakeholders were not designers.

ACKNOWLEDGEMENTS

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A REFLECTION ON THE PRODUCING, DELIVERING AND RE-USING 'ASSETS' FOR MOOC'S

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ABSTRACT
Massive Open Online courses (MOOC) represent a new emergence in how the delivery of academic learning is evolving and engaging with platforms that endeavour to reach and engage with a diverse cohort [1].
The emergence of this new platform has raised questions about best practice on the delivery of a MOOC with little still known about the impact this format has had on knowledge development. As a consequence of this limited understanding a requirement exists to develop a deeper understanding of the phenomenon so that we can use this tool to engage with a generation that absorbs information and learning in a different way than any generation before it. It also raises concerns about best practice for asset creation.
This paper is a reflection of the design and development of assets as well as the delivery of a successful MOOC. The MOOC received a highly commended award at this year's international Medea awards with 237 entries from 29 countries and the judging panel was made up of 112 judges. We reflect on the undulating journey undertaken with a view to highlight some of the positives and negatives of our expedition. We are doing this as we feel the MOOC format has many added benefits to learning but there are lessons learned from both a management and pedagogical perspective that could turn this format into a real asset for academic learning.

Keywords: MOOC, development, creation, process, innovation, learning, asset creation.

1 INTRODUCTION
Massive Open Online courses (MOOCs) are seen by many as a novel and relevant means to engage a wider student base [2]. It is also a good means to disseminate up to date research to audiences that may have no other means off accessing this type of research.
To date there has been some research on the demographics of the learner [3], others have looked at the pedagogy at the heart of a MOOC [4] [5], while there are those who have debated the very point of the MOOC platform itself [6]. What we wish to present here is a reflection on the practices and processes used to create a MOOC. This paper reflects the lived experience of the process of, designing, building of assets and the delivering a MOOC over a 12 month period.

2 METHOD
The methods used here are both qualitative and quantitative in nature. Both statistical and interview data collected from both the end users and those involved in the creation of the MOOC. These methods are used to paint a succinct picture of what took place and point to areas for development that could lead to best practice approach.

3 CONTEXT
Our MOOC, endeavoured to engage with the diverse topic of innovation from both a technical and social perspective. As a consequence of the complexity of the topic, our MOOC consisted of a multi-team system consisting of four educators from faculties across the University; School of Mechanical Engineering, Business School, School of Design and the Lifelong Learning Centre as well a number of support staff from the Product Design cohort. The MOOC was also developed with the support and supervision of a University's Digital Learning Team.

The framework for the MOOC consisted of a three week course and was launched on the Futurelearn platform in September 2014. It used a series of relevant case studies as the central spine of the learning journey. These case studies, often in video format, were a mix of innovation stories from business and research projects from across the University. This blend of business and research case studies provided the participant with insights and practical examples of innovation in business and in a research based university.

4 DESIGNING A MOOC

A MOOC is a platform for learning that has the capacity to engage with a wide variety of learners. What makes this platform particularly distinctive from other online and blended learning approaches is that the courses are aimed at a *massive audience* which are often measured in 1000s, open to all, free to participate with 100% delivered online.

The standard construction for a MOOC is a number of video assets arranged chronologically and purposefully interlinked to provide a clear pathway of delivered learning. Depending on the subject matter, and the techniques supported by the online platform, learning is reinforced with techniques as background reading, listening to audio files and linking to other online materials. Learning is further deepened using other blended learning techniques such as discussion on blogs, forums and online chatrooms, with understanding checked using online MCQs or peer reviewed assignments. In some cases there are summative exams at the end of the MOOC.

4.1 Designing the Learning Journey

From the early days of creating the MOOC, a large degree of emphasis was placed on what we wanted learners to understand and when i.e. *who are we talking to?* and *how will they absorb the information?* This 'learning journey' was broken down into activities (see Fig 1). A clear and consistent style was sought, that engaged, challenged and embraced the topic while still accessible to the target audience.

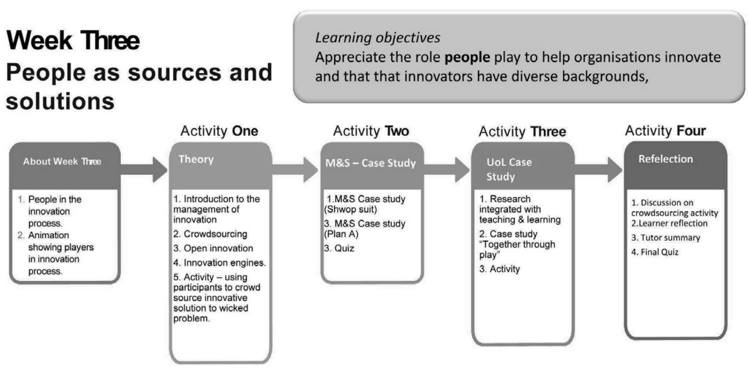

Figure 1. Leaning Journey Map, courtesy of Carol Elston

The nature of assessment in this style of learning is still being developed. The approach taken here engaged with tools and techniques that allowed participants to *'check your understanding'* at regular and predesigned intervals throughout the process (see Fig 1, activity four). These tools consisted of multiple choice questions, as well as the promotion of discussion through the online forum.

5 CREATING ASSETS

The video material, referred to as 'assets' is often one of the main ways of delivering content. During the development of this MOOC a number of approaches were used to generate the video content. For the academic team, this proved to be one of the most time consuming aspects of MOOC development and construction. As a result, a large section of the paper is given to the processes involved in the making of the video 'assets' and consists of a reflection on the techniques used.

The tutor based video format was seen as an integral part of the MOOC experience as through this medium we provided a means to give a face to those at the limits of the cutting edge research. We felt that the element of time with tutors and researchers would add value to the experience. This was later confirmed in feedback received from participants both during and after the course. Our digital learning team advised that length of the asset was to be kept short at around 5-7 minutes to maintain attention of the learning, an area which has been the focus of emerging research in this area. [7].

5.1 The Interview

Several of the assets in the MOOC were created using interviews. The interviews were used to collate first hand experiences as case studies. Some case studies involved just one '*storyteller*' others were more complex engaging a number of contributors to fully explain the case study. We found this to be an excellent format for discovering and unearthing very rich information and experiences. One learning outcome was that the post interview editing was very time consuming. One reason was that interviewees did not always provide the answers you were expecting or wanting them to provide. Another reason was that watching, re-watching ordering and editing a video sequence to tell a cohesive story was a new skill for the educators.

Here are a few tips to gain the most from an interview style asset and support the reduction of the resultant editing work.

- Prior knowledge of the case study is essential to enable the interviewer to compile a set of questions to guide the interviewee. The structure, chronological order and content of the answers can be established this way.
- The way in which the questions are asked has a distinct impact on how the interviewee will phrase the answers you require. Expect to ask the same question in several ways to gain the best response.
- The interviewee should be encouraged to repeat the question in the answer. This enables the questions to be removed from the film without losing any meaning.
- Press the interviewee to keep answers very short. This allows more flexibility in the editing of the film. We found that it is surprisingly difficult to obtain short answers from some interviewees. Often footage before editing was five or six times longer than required, for example 30 minutes for a 5 minute asset. If each answer lasts 60 seconds and you have four interviewees for a case study, this limits your selection to one answer per participant.
- Some interviewees have hidden agendas and focus on points which may not be relevant.
- It is important to provide an overview of the intended message of the interview in advance.
- Their first answer was often their best so ensure you record this.

5.2 The scripted theory mini lecture

In a lecture situation, which many academics would be familiar with, slides may be used to prompt the flow of information from the lecturer to the students. The script is unwritten and the performance often unrehearsed. We found that it was surprisingly difficult to reproduce this kind of flow of information in a filmed situation. The change from a 50 minute length to a 5 minute length adds pressure to be succinct and deliberate. Any pause is noticed. There isn't an audience present which noticeably changes the dynamics of the 'performance'. It was also very easy to stray from the intended point.

Writing a script creates the additional problems that the text needs to be learnt and delivered almost word for word. Some presenters have the skills to do this, other do not. A teleprompter, as employed widely across the media was introduced to support this activity with excellent and almost instant results. Presenters found the format easy to prepare and practice for by using an app on a tablet. Here are a few thoughts and tips to gain the most from the use of a script.

- The script needs to be written in a style which the presenter can easily read out loud.
- Delivering the correct intonation for words within each sentence required practice and rehearsal.
- Timing of the asset can be estimated in advance and carefully planned using word count for a number of seconds.

One learning outcome for the developer is that a written script delivered using a teleprompter is a very quick way to create learning assets. Information is succinct and delivered as intended. Any animation such as images and titles can be pre planned and if highlighted in the script, simply integrated into the asset. We found that this style of asset creation significantly reduced editing time later as only the errors need to be removed. Another benefit was that the transcript was already written to include in the MOOC.

5.3 The Ad-Lib presentation

Some academics and presenters do not wish to be held to a written script. They may be more comfortable just talking about a subject and knowledgeable enough to talk fluently and lucidly with ease. This can be the case when the academic is experienced and the subject is core to their area in teaching or research. This format delivers a fresh presentation style which is engaging and natural however, it did have its' limitations as explained below.

- This style can deliver explanations which although perfect for a lecture theatre may be overly long for a MOOC.
- The structure of delivery can be out of order.
- Editing down an ad-lib session is difficult and requires someone with time and a good knowledge of the subject.

5.4 The Journalistic approach

Some of the assets in this MOOC focused on learning from case studies. These included research based case studies and historic case studies from a company archive. The approach to building an asset to present the case study is almost like one of a journalist covering a story. A great deal of work is initially required to familiarise oneself with the subject, the contributors and the story behind the case study. In several of the assets on the MOOC, interviews with participants and existing films were interlinked using short mini-lecture sections to provide the theory. Given the issues around producing interview based assets and mini lectures already discussed, the combination of these in terms of structuring and editing proved very complex.

- Where and when the interviews are located needs careful planning. Many locations are just too noisy to film during working hours.
- Existing footage requires consideration in terms of ownership and copyright.
- Ensuring a cohesive story is presented using several viewpoints in a short space of time is tricky. The editing time can be long and complex.

The journalistic style is time consuming in both preparation, filming and editing, however, the results can be engaging for the learner with multiple presenters and real life experiences.

6 GETTING THE MOST FROM YOUR ASSETS

Developing assets for a MOOC is without doubt expensive for any institution, the main costs being associated with a combination of the production team such as cameraman, editor, transcriber and the academics time to conceive, write, practice and deliver. To get the most out of this investment of time and energy, should be developed in a format which allows future use in multiple learning situations. One expectation was to re-use our assets within blended learning modules, particularly the online case studies. Having developed a variety of assets for the MOOC and later attempted to re-use materials, it became clear that we had not fully considered the importance of producing materials which were fully independent of the MOOC structure.

The following list provides tips for developing independent assets. The content of each asset should be constructed such that it can exist on its own without the support or context of the MOOC structure.

- Each asset should not refer to or be dependent upon material in other assets. For example, they shouldn't refer to the next or previous assets or materials.
- Assets should not refer to being part of a MOOC (or module) in any way.
- Any graphical devices such as titles should not refer to the MOOC (or module).

In some cases it may be important to have an introductory section or title which introduces the subject of an asset to explain its purpose within the learning journey of a MOOC. This can be achieved with a separate asset or a section of the asset which can be easily cut or edited out of the main section of the asset.

7 ONLINE PHASE

The data used is a snap shot, taken immediately after the running of the MOOC. The findings here are based on questionnaire and comment feedback received from 300 participants, who completed the MOOC within the designated time frame, however it must be noted that more of the 15,000 who started the MOOC have now completed the course as it remains open to them. Of those interviewed, 93% have completed the MOOC with 7% failing to complete and 1% not taking part once they had signed up. Figure 2 highlights the breadth of territory that this involved.

Figure 2. Map of participants (Courtesy of Futurelearn/Google)

The type of participants engaged with the MOOC was diverse on many levels. This diversity expanded across many forms, such as: technical ability, accessibility to materials and the level of prior knowledge to the subject matter. As a consequence of this diversity the management of the MOOC became extremely important.

Many of the participants needed assistance in navigating through the web pages, with one noting that she was *'not a facebook user';* while others had difficulties due to the limitations of PCs or internet access in that area. As a consequence some of the participants relied on the written documentation provided as they could not use the video formats. The use of dual learning formats was seen as a key strength to this MOOC, as it facilitated both different learning styles and the limitations of local technology capabilities.

This MOOC was created for and pitched at those with an interested but limited understanding of *innovation* in its broadest sense. However some of the participants had a high level of understanding of the topic while others did not. As a result some found the teaching material easier than others. Many of those with a high level of knowledge in the area did engage with discussion which often led to a deeper level of understanding from other participants. However a small number of negative or 'trolling' comments had to be managed by the support team.

8 MENTORS AND MENTORING

The online support system to support the 'live' MOOC consisted of team of mentors and educators. This process was led by; the educators, the various subject experts who appeared in or contributed to the case studies and masters students who had been trained in online support.

A structured approach was taken to the management of this team as it was run mid-term with both academic and support staff alike having to engage with the management of this MOOC around everyday working practices.

The timeline for the MOOC was shared online, with participants encouraged to keep pace with the rest of the cohort. This provided a focus to enable the educators and mentors provide targeted online support in the appropriate forums.

- Welcome and directional support was given to every participant. Feedback from participants reflected positively to this initial engagement highlighting that it gave a sense of community and belonging to the learning journey.
- Participants expected high level answers to their specific question.

There were a number of lessons learnt:

- Cultural sensitivity; the use of various syntax was seen as offensive to some respondents. For example one mentors used an exclamation mark when saying 'hello!' in a welcome comment, this was met with a high level of disdain resulting in a need to clearly explain that it was not meant in offence. There is a need to provide cultural sensitivity training for staff supporting the online forum.

- Feedback has shown that when those educators involved in that particular weeks' video were visible on the discussion board, participant satisfaction improved.
- The mentors highlighted that the management of the MOOC took place in personal time, mainly in the evenings and weekends.
- The mentor program was managed through the creation of an excel spread that clearly identified each person's role and when they were due to take part.

From online comments it was clear that online presence, particularly by the educators was very much appreciated by the participants.

9 CONCLUSIONS

The aim of this paper was to share our experience in the development and delivery of a MOOC. We have attempted to highlight some of the key learnings from our experiences, in an attempt to improve a format that we believe can aid in the dissemination of academic knowledge to a wider audience.

Since delivering the MOOC we not only realised the value of the assets we had personally created, but more importantly we realised the value of each other's assets. Recently we have started to include them to enhance learning situations in our own faculties. This sharing of material cross faculty was an unexpected and valuable outcome of generating video assets for a multi-disciplinary MOOC. Video content full of rich material and experience which can stand alone, be easily transplanted, can be reused to form part of new learning 'packages'. Such online material fits well with flipped classroom techniques increasingly adopted in Universities.

Creating learning materials for such a wide audience fine tunes your knowledge and understanding of producing accessible material. Key elements identified from our experience include the need to have a clear understanding of what you are attempting to deliver and who you are delivering too. We have shown the need to deliver materials in a number of formats, due to the various contextual and learning capabilities of the participants of the MOOC. We have shown that a combination of video and written formats received high levels of engagement. Something we as a group will be carrying forward.

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MULTIPLE MEDIA STIMULUS IN PRODUCT DESIGN TEACHING: THE IMPORTANCE OF RICH MEDIA ENVIRONMENT

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ABSTRACT
This paper investigates how a rich media environment influence student's learning outcome within industrial design education. Through a case study focusing on a student project in product design, the prerequisites for learning outcome have been assessed, with the aim to improve our product design curriculum on undergraduate level. The student's intrinsic motivation for work seems dependent of the pedagogical inspiration and facilitation of media, methods and tools provided by the educators. Exposure to diverse combinations of specific learning media builds valuable stimulus for creativity. This paper explains in particular what kind of media that may influence positively to student's individual progression and learning outcome. In this setting, we acknowledge that multiple media stimulus becomes catalyst for building knowledge, skills and a certain designerly confidence. While being unexperienced students on undergraduate level, the exposure to new methods, tools and media seems crucial in order to build the necessary level of knowledge and self-awareness. The findings suggest that the facilitation of multiple media stimulus through a rich media environment may produce increased learning progression through the learning journey. The individual choice of these learning media seem to determine the specific outcome of each individual student's learning progression and the character and quality of each student's materialized submissions.

Keywords: Multiple media stimulus, rich media environment, learning outcome, facilitation, case study.

1 INTRODUCTION

As the design field develops away from physicality towards conceptualization and immaterial media on digital platforms, 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. We acknowledge the importance of teaching industrial design students efficient design methods in order to provide them with creative skills and practical abilities to develop relevant solutions for corporate use in industry. Today, a common comprehension is that the importance of design students' skills within product design is diminishing, while the value of interaction design and service design skills is considered to be strongly increasing. We also acknowledge that even though disciplines such as interaction design and service design are commonly facilitated through digital media, these disciplines are also in most cases dependent on facilitation through physicality. Physical products are still needed, and as a consequence of this, we support the idea of initially making design students able to build experience from investigation and experiments through basic product design assignments on foundation level, prior to more advanced disciplines such as interaction design and service design. It is commonly understood within creative disciplines that a rich media environment - in general - may support the outcome of creative processes. However, there is a limited amount of research in this field, and there is a need for stronger research on what kind of stimulus that enhances creativity in product design education in academia. This situation asks for a more in-depth study on how stimulus will influence the students' development through concrete product design assignments, and this study seems to be relevant for creating this insight from product design education at tertiary level.

There are several aspects that may influence learning environment. One could argue that even the physical learning space could be defined as part of a media environment, as space may influence how learning is executed [1, 2]. In addition to the influence gained from external media, student capability parameters [3] are another aspect that determines to what extent an efficient learning journey is accomplished in academia. Parameters like mission, number of participants, age span and gender distribution in groups should be considered as relevant premises for creative thinking during product design assignments. However, due to the complexity that integrating learning space and student capability parameters would implicate, both these aspects are deliberately exempt from this study.

1.1 The scope and design case

The scope for this study is a design case where a group of industrial design students on foundation level were asked to develop three sets of cutlery: a disposable cutlery, an everyday cutlery, and a "fine" cutlery. Each set of cutlery was supposed to consist of a minimum of three elements; knife, spoon and fork. The students were supposed to document one of these sets of cutlery through computer drawings using 3D CAD SolidWorks software. As a starting point, the students were asked to investigate aesthetical expressions through exploration of individual materials. Furthermore, the students were encouraged to explore through individual design processes, and to individually choose the order of activities, different media exposure and optional working tools throughout their exercise.

1.2 Research methodology

Our research methodology has mainly been focusing on student behavior. Three different research tools were used in this study; observations of the tutoring sessions in the workshop and in the studio, photo documentation from the workshops and studio exhibition, and finally a written questionnaire.
Our research question was: What kind of media build valuable stimulus for creativity? Through the cutlery design project as case study, this study investigates in particular on what kind of media exposure that contributes positively to strengthen students' design process or generate new ideas.
Our hypothesis is that the combination of various kinds of stimulation from media will determine the outcome of each student's assignment, in terms of creative production of ideas and design solutions.

2 THE STUDY

The observations of students took place in different settings through the assignment. As part of the introduction to the cutlery design assignment, an initial workshop was carried out - figure 1 - with the aim to establish a certain awareness on the context and environments that a specific type of cutlery usually will be part of. In this workshop, existing cutlery was used in order to prepare the students for aesthetical assessments, where the students were encouraged to assess whether a given set of cutlery would suit a certain user setting or atmosphere. There are several advantages of this procedure: it stimulates the students' language and communication skills, and the tactile contact with physical artefacts builds experience and consciousness around both user behavior and common etiquette. Studying aesthetical and functional relations between each element of the cutlery adds to this insight.

Figure 1. Initial workshop

Facilitating the right mind-set for creative thinking [4] is crucial in design education. Our ambition was to create a stimulating environment for the students during the initial phase of the assignment, as base for a generative process enabling the students to develop ideas and concepts while 'swimming in inspiration'. In addition to facilitating the workshop, a series of initial, inspirational lectures were given, in order to build a basic knowledge about cutlery as phenomenon.

Figure 2. Sources of inspiration

The students were exposed to different media and situations - figure 2 - spanning from research using photo-documentation, excursions to domestic household stores, search for vintage cutlery with historic value, discussions with other students and teachers, initial research on user behaviour, internet search, developing product design specifications, searching relevant literature in library, tutoring, 2D concept sketching, 3D CAD tutorials as well as group reviews.

Figure 3. Pre-making stages – visionary mind-sets

The ability to make design representations is a vital skill in design process [5] and the ability to communicate visions for a new design solution is if paramount importance to product designers and this supports the idea of raising visually literate students [6]. As a consequence of this intention, efforts were made to develop visual communication skills during drawing exercises. Figure 3 presents photo-documentation produced in different situations from the research and the initial idea generation.

Figure 4. Diverse media environment - in the making, and example of final result

In a typical design process consisting of analysis phase, ideation phase, concept phase and detailing phase, different tools are used dependent on timing during the project. While the use of investigative sketches is typically reduced, the focus on sketch models and final presentation models increases during the process [7]. In order to stimulate the exploration through individual processes, we encouraged the students not to be bound by this pattern. Figure 4 exemplifies some of the diverse media environment that the students had access to during their assignment, including 3D computer lab where CAD drawings were made, plastic workshop and metal workshop. Finally, a presentation model is displayed in order to stress the importance of physicality being a paramount element of the creative journey, as the careful and generative processing and development of sketch models constitutes a significant stimulation as well as a required activity during the design process.

2.1 The Questionnaire

In order to obtain an in-depth understanding of the experiences that the students gained through the assignment, a questionnaire was separated into four different tables; (1) Statistics on distribution of gender and age, (2) Qualitative feedback from cutlery project, (3) Environmental stimulus overview, and (4) Description of other sources of inspiration / media / activities.

Table 1. Questionnaire - Statistics, distribution of gender and age

Total no. of respondents:		19
Male, total:	18 y -	7
Female, total:	18 y -	12
Male	18-20 y	2
	21-23 y	3
	24-26 y	0
	27-29 y	2
	30 y -	0
Female	18-20 y	0
	21-23 y	8
	24-26 y	3
	30 y -	0

Table 1 indicates that from a total of 19 participating students, there were 7 male individuals, and 12 individual females. The major group of similar age was 8 females in the age group of 21-23 years.

Table 2. Questionnaire - Qualitative feedback from cutlery project, post-perspective view

1.	*"In the cutlery project the knowledge of the context around the cutlery was crucial for the design solution".*	Do not agree	1
		Partly agree	10
		Quit agree	7
		Totally agree	1
2.	*"In the cutlery project I discovered new sources of inspiration along the way, which made my cutlery better".*	Do not agree	2
		Partly agree	5
		Quit agree	7
		Totally agree	5
3.	*"It is important for me to have access to many different sources of inspiration throughout the design process".*	Do not agree	0
		Partly agree	*2*
		Quit agree	8
		Totally agree	9

Table 2 provides feedback on how diverse media environment would influence the students' design processes. Q1 confirms that a major number of students - 17 of 19 – partly or quit agreed that knowledge of the context around the cutlery was crucial for the design solution. Q2 indicates that inspiration does not only occur as part of the initial research phase, but even more occurs along the way, during the project. In Q3, a vast majority of the students confirm the importance of having access to many different sources of inspiration throughout the design process. A rich media environment seems crucial for establishing a broad and diverse platform of inspirational resources necessary for producing a strong body of ideas and concepts, before going through a selective process.

In our search for detailed feedback from what students experienced as positive influence from environmental exposure, table 3 asked for specific sources of inspiration, media or activities that contributed positively to strengthen students' design process or generate new ideas, based on multiple choices. The questions were divided into four sub-categories: Human resources, physical / environmental resources, methodological resources / activities, and other activities / resources.

Table 3. Questionnaire – environmental stimulus overview, post-perspective view

"The following sources of inspiration / media / activities contributed positively to strengthen my design process or generate new ideas" (tick several boxes if necessary):

Human resources:	
Teachers	12
Workshop Teachers	12
Parents / family	5
Friends	8
Discussion with other students	16
External people	3
Physical / Environmental resources:	
The library	2
The workshop	17
Books / literature	15
Drawing utilities	7
Film / Video	5
Log	1
Internet	16
Sketch book	7
Diary	0
Model building	12
Hobbies	8
Art	8
Games or 'play'	4
Physical activity	3
Experiences in nature	3
Methodological activities / resources:	
Switching method	4
Changing the environment	5
Changing tools	2
2D sketch work	11
Building 3D models	13
Guidance / tutoring	14
Mid-project reviews	8
2D Data	1
3D Data	3
Other activities / resources:	
Meditation	2
Peace and tranquility	9
Alcohol	1
Music	8
Dreams (while sleeping)	7

0 5 10 15 20

Table 3 of the questionnaire provides an extensive feedback from a broad scale of stimuli. Spanning from an abstract level consisting of physiological conditions (dreams etc.) to concrete media (sketch book etc.) this approach aimed at capturing a wide selection of influence from a broadest range of different media exposure. The students were enabled to tick several boxes if necessary.

- In the 'Human resources' category, especially discussion with other students and teachers as well as workshop teachers contributed positively.
- In the 'Physical / environmental resources' category, especially the workshop, books / literature, internet and model building contributed positively.
- In the 'Methodological activities / resources' category, especially the guidance / tutoring, building 3D models and 2D sketch work contributed positively.
- In the 'Other activities / resources' category, especially peace and tranquility, music and dreams (while sleeping) contributed positively.

Table 4. Questionnaire – Description of other sources of inspiration / media / activities

Please specify other sources of inspiration / media / activities:
- 'To explore the shops, see diversity and range of cutlery'
- 'Cartoons and animation'
- 'City tours, visiting shops'
- 'Joint projects stimulates community in class'
- 'Everything!'
- 'Taking a break from work, get distance and then come back with a slightly different angle / perspective'
- 'Relaxation from the project to gain new joy, spark and motivation

In order to collect qualitative feedback from strictly individual experiences during the design process, table 4 was added to accumulate personal notations. These answers are diverse, but reflect - amongst other - the positive experience from observing the range and diversity of existing cutlery.
One interesting aspect from the questionnaire is that only one student had actually written a personal log during the assignment. In a post-perspective view the students agreed that they would benefit from making a log, not only to get a track of their disposition of time, but also by making an over-view of their total exposure to different media, activities and inspirations that in total gained their process.

3 CONCLUSION AND REFLECTIONS

A major intention with the design project was to encourage the students into seeking different external stimulus through different media. One could argue that exposure to these different sources of stimulation is regarded as a methodological approach, and thereby complying with our initial intention to strengthen our research on design methodology in product design education on tertiary level.
It seems that our hypothesis mainly has been confirmed by the fact that the feedback gained from observations, photo-documentation and a written questionnaire indicate that exposure to a diverse range of media actually influences the outcome of creative processes. However, in order to build a more solid body of evidence, a larger group of students should be included in our study, and this would be relevant for a continuing, future study. A long-term study would contribute to this insight.
The importance of a rich media environment seems crucial for design students while being in creative mode and for us being tutors and researchers this study has been valuable as tool for producing new insight into what kind of stimulus that different media generate. It seems that the diversity of inspirational resources from a rich media environment is the key to obtain the necessary stimulus that students will most efficiently gain from in their creative processes through their learning journey.

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CONDITIONS FOR THE PROMOTION AND DEVELOPMENT OF CREATIVE INDUSTRIES WITHIN HIGHER EDUCATION INSTITUTIONS

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ABSTRACT
Higher Education Institutions (HEIs) play an important role on the promotion and development of creative industries (e.g. product design companies). These roles, however, are not clearly defined. Previous studies by the authors, conducted in Colombia, encountered several critical internal factors as well as environmental relationships proper of the ecosystem of business that affect performance in creative industries. HEIs can promote specific activities to become agents that enhance the development of these creative industries, thus contributing to overcome environmental and critical internal factors. This paper presents a model that can serve as a starting point within HEIs to establish policies towards this goal. For such purpose, the present research extended the aforementioned studies to Argentina and the United States, countries recognized worldwide for the development of "creative industries" or "creative economy". Fieldwork was performed in nine cities: two in Colombia, two in Argentina and five in the United States. Data was collected via interviews and focus group studies conducted at universities and creative industries, as well as with experts, government representatives and support organisations. A PESTEL analysis was used to identify weaknesses that could become opportunities for action within HEIs. The results allow for the establishment of nine key roles of the HEIs (i.e. education, moderator of the ecosystem, research, foster discussion, investment, on-going support, dynamism, joker, and simulation/real environment) that can be related to these institutions' substantive functions (i.e. teaching, research, extension, and support and integration), which contribute to enhance the development of creative industries, their growth and long-term sustainability.

Keywords: Creative industries, creative economy, role of higher education institutions, PESTEL.

1 INTRODUCTION

In the last years numerous studies have been conducted to understand the economic phenomenon of creative and cultural industries [1], [2], [3], [4], [5], [6]. "The new creative-cultural industries have progressively transformed into one of the main sources of production and employment for many countries" [7]. The studies show that these industries have been gaining territory in regional and international markets, amounting to a considerable economic participation. It is estimated that the cultural and creative industry represents between 3% and 7% of GDP in different countries.

Previous studies have allowed the identification of non-existing or non-adequate mechanisms to provide support to the real and particular needs of cultural and creative entrepreneurs, their dynamics, and the speed at which the sector changes. It was evident that there are many empirical initiatives of self-education and self-training undertaken by industries in the sector, which cause a disparity between the companies; this result in difficulties to materialize certain partnerships such as associations or guilds, and to make possible service or product exchanges, sustainability, international projection, and growth.

Along this same topic, it was possible to observe that support has been limited to general courses that, in the best case scenarios, try to extrapolate the tools that have conventionally served other types of industries, such as technology-based or manufacturing ones, ignoring in many cases the particular dynamics and specific necessary for the creative industries' development. Similarly, it was found that entrepreneurs have a low level of professionalization, and their experience does not count for the existence of support and education for the sector. Furthermore, the aforementioned studies also indicate the lack of consensus, regarding the formalization and education schemes the sector needs from the HEIs. This leads to promotion and development schemes that are not wholly pertinent, and that are essentially empirical, resulting in unsatisfied entrepreneurs when they seek for help.

The Research Group on Innovation and Entrepreneurship together with the Design Engineering Research Group at Universidad EAFIT conducted this qualitative research in Colombia, Argentina and the United States with the purpose of identifying the main actions that HEIs should carry out to create an environment that promotes the creation, establishment, development, growth, and evolution of cultural and creative industries (CCI). This study shows that HEIs can perform diverse, varied, and unusual roles in regards to each one of its functions. This statement is a considerable finding since it serves as a guide to reflect on the actions of HEIs, keeping in mind that the substantive functions do not end in themselves, that is, teaching does not end in the classroom, research does not end in the lab or in a report, and extension is not only continuing education courses. As can be observed, each role represents great possibilities and responsibilities for each one of the substantive functions.

2 RESEARCH METHODOLOGY

In the current research, of qualitative approach, focus group and in-depth interviews were used for data gathering. Four target groups were selected for such purpose: students, entrepreneurs, professors, and experts in the field. In the cases where in-depth interviews took place, due to the difficulty to gather target groups for a focus group, the interviews assured there would be enough quality information for the analysis. This process was followed for all the cities included in the fieldwork: Bogota, Cali, Medellin (Colombia); Lujan and Buenos Aires (Argentina); Los Angeles, San Francisco, Redwood, Pasadena, and Palo Alto (United States).

Table 1 shows the detail of the testimonies gathered, according to each target group in this research. The totals in this Table do not correspond to the total number of people interviewed, since some of the interviewees were considered in more than one category of target group. The category "Expert Testimonies" emerged during the development of the project, since in each region it was possible to identify key people whose testimony added valuable information to the research.

Table 1. Testimonies by Country

Country	City	Entrepreneurs	Students	Professors	Experts
Argentina	Buenos Aires	5	5	3	13
	Luján	1	0	1	1
Colombia	Bogota	2	10	7	4
	Cali	3	3	3	2
United States	Los Angeles	3	0	1	1
	Pasadena	2	0	0	0
	San Francisco	2	0	2	3
	Palo Alto	1	3	1	0
	Redwood	2	0	0	0
TOTALS		**21**	**21**	**18**	**24**

The information was processed from the transcripts of the focus groups and the in-depth interviews and, later on, analysed based on the frame of the PESTEL analysis [8] using content analysis technique. This process was divided in two phases:

- **Phase 1:** The information obtained was identified, classified, and analysed. These activities lead to common trends, shared opinions, divergence points and, conclusions for each target group.
- **Phase 2:** In this phase the idea was to identify the convergence of the different target groups, in order to ascertain conclusive points regarding the outside environment, the role of the HEIs, and the opportunities for action to strengthen and promote CCIs.

3 RESULTS AND FINDINGS

Even though the particular analyses account for political, economic, social, technological, environmental, and legal conditions of each region, the Research Groups arrived at a series of incidental findings labelled as "Dynamics", which resulted from grouping the weaknesses identified in

PESTEL. They were categorized as dynamic, since this term describes the factors (in this case weaknesses) capable of altering a physical system (the CCIs ecosystem). Upon grouping the weaknesses, dynamics had to be considered in order to identify possible compatibility. Lack of compatibility led to create a new dynamic that refers not only to the possible role of HEIs in the promotion of creative and cultural entrepreneurship, but as a characterization of a certain set of conditions that, in light of the testimonies gathered, must be taken into account for the development of such entrepreneurship. The mentioned "Dynamics" transcend the scope of action within HEIs, but condition and limit it: entrepreneurship, effectiveness of the ecosystem, country prospects and vision, work dimension, archetypes, market, strategic efficiency, social dimension, environmental issues, security, identity, follow-up in the sector, education, industrialization and development, regional integration, investment, update, industry valuation, involvement of the companies in strategic actions, outside influence, and understanding and transformation of the industry.

Nevertheless, and regarding the scope of this research, the conclusions focus on the roles that are inherent to the HEIs in terms of their direct actions and of their substantive functions: teaching, research, extension, and support and integration. Table 2, below, shows the 9 roles identified for HEIs.

Table 2. Roles of HEIs

ROLE 1	Education	Refers to everything related to education, not just from the delivery and construction of interdisciplinary knowledge, aligned with practice and industry reality, but also from the reinforcement of imaginaries, values, and criteria, plus advisory and training. This education requires pertinence, integrality, transversality, and connection with reality.
ROLE 2	Moderator of the Ecosystem	Implies the articulation and harmonization of the factors that compose the system and with them the establishment of contacts, bridges, and networks that allows them to have two-way relations, exchanges, and feedback in a healthy and effective way. Furthermore, it has to do with its own participation and involvement with the sector.
ROLE 3	Research	Begins at the fostering and promotion of research, extending to pertinent research, and finally ends in useful and concrete products which serve as a valuable input for different interest parties. It also includes experimentation through trial and error.
ROLE 4	Foster discussion	In order to guarantee the generation of new knowledge, adequate to context, not having to copy other models. This includes thought, conceptualization, prospection, critique, and debate.
ROLE 5	Investment	Refers to the resources at the service of education, financing, and incubating projects, or attracting others to provide those resources.
ROLE 6	On-going support	Related to the support for alumni in terms of constant training, advisory, and education, as well as assessment to their careers or their entrepreneurial ventures.
ROLE 7	Dynamism	Implies moving to the rhythm of the world, the market, and technology. Requires great flexibility to adapt strategies, tools, methods, curricula, amongst other issues, and generate new actions that respond to current threats and opportunities.
ROLE 8	Joker	It is expected that HEIs identify the voids in the ecosystem, those fronts that are not being covered, and direct their efforts to fill such voids in such a way that fluxes are not interrupted there.
ROLE 9	Simulation of real environments	Implies the fostering of academic environments in which students can practice and test their knowledge and skills based on the rec-creation of actual contexts and situations. Simulators, role-play, and other strategies may be used.

The findings drawn from this analysis were organized keeping into account the substantive functions of the HEIs that, for this research, are the following:

- **Teaching**: All activity that impacts quality and characterization of curricular design of practice-oriented education programs.
- **Research**: All activities related with the generation of new knowledge that feeds the University and its essence.
- **Extension**: All activities related to continuing education in the areas of knowledge and expertise of the university, and activities that support and promote knowledge for the benefit of the community.
- **Support and Integration**: All activities that complement the possibilities and richness of the other three, but that are not necessarily tied to a specific knowledge of the university, but to the role it represents in society.

The last function of "Support and Integration" emerges as additional to the traditional substantive functions (Teaching, Research and Extension) since certain situations call for HEIs to act in a context that is more related to their capacity and intention to impact society. The characterization that follows of the Roles in relation to the Functions of the HEIs responds to the particular and forceful needs for the promotion of creative and cultural entrepreneurship within HEIs. Table 3, below, shows the relation between the substantive functions and the identified Roles.

Table 3. Relation between substantive functions and Roles in HEIs

	Teaching	Research	Extension	Support and Integration
R 1: Education	x	x	x	x
R 2: Moderator of the Ecosystem	x	x	x	x
R 3: Research	x	x		
R 4: Foster Discussion	x	x		x
R 5: Investment	x	x		x
R 6: On-going Support			x	x
R 7: Dynamism	x		x	x
R 8: Joker		x		x
R 9: Simulation/ real environments	x	x	x	x

The Table shows that the new function identified of Support and Integration has a fundamental role since it calls for HEIs to become third generation institutions [9], with a scope that transcends traditional endogenous functions, in the sense of them being education and research centres, but becoming more relevant in the modelling of society, and in a more direct and active relation with it. Similarly, it can be observed that the traditional functions are perceived as more robust, going beyond the simple definition of teaching, doing research, and offering continuing education programs. The configuration of these findings allows HEIs to identify strategic areas for action, depending on the contexts and resources available to each HEI, it also aids in the design of strategic plans that seek to promote the development of creative and cultural entrepreneurship.

4 DISCUSSION AND IMPLICATIONS FOR HEIs AND PRODUCT DESIGN ENGINEERING EDUCATION

HEIs can perform many, varied and unusual roles regarding the substantive functions. This statement is in itself a significant finding of this research because it guides the reflections on the actions of the HEIs, understanding that the substantive functions are meant to be enhanced; this means that teaching does not end the classroom, research extends beyond a laboratory or a research report, and extension is not reduced to continuing education courses. Each of these roles represents an enormous scope for action and responsibilities associated to each of the substantive functions.

Teaching calls for a theoretical and practical education, strongly related to all areas of cultural and creative industry. This allows product design engineering students to be aligned with the professional exercise and also to develop the necessary competences, essential for business practice. Similarly, contextualized and globalized education should be offered without sacrificing the needed expertise in different areas of knowledge around product design engineering. Since this is a profession that requires specific knowledge, education oriented to develop skills in arts and technology is fundamental, geared not only to the development of talents, but also to critical thinking in the individual to face the challenges of creative economy. General education and other extrapolated knowledge –transferred from other fields without special consideration to the particular requirements of the cultural and creative industry– proves to be increasingly irrelevant and inadequate to meet the challenges and opportunities faced by the industry.

Correspondingly, Teaching, as the means for the integration of knowledge, should promote interdisciplinarity. This requires keeping up with the ever-changing pace of the industry to be at the forefront of knowledge, and adapt to new needs and learning opportunities that arise for the industry. Education needs to be open to new possibilities mediated by ITs [10], which involve a different form of interaction in classrooms and require the development of new skills for both: teachers and students. In addition, Teaching requires the application of best practices, and is called to be competitive not only in comparison between institutions, but also in relation to market requirements, and to the challenges the industry faces.

Finally, the role of Teaching is also called to educate in the discipline of research work, which is closely related to the innovation capacity of the industry, allowing it to work for its development and continued growth. Product Design Engineers trained in research skills have the ability to do competitive intelligence and manage resources necessary for product innovation and the creation of R&D areas.

The **Research** function finds new paradigms. While research undertaken by HEIs is key to the development of knowledge and the promotion of innovation, this function transcends the development of research as part of the in-class academic work, and faces the institutions with the need to create practical, active and applied knowledge; making it visible not only in academic media outreach, but also through those means that allow all stakeholders of the cultural and creative industry to access information constantly and regularly. The knowledge generated by research must feed the debates that seek to shape market conditions and regulatory frameworks that affect the development of the cultural and creative industry. Researchers should be active and participative working with the industry, being the bridge between theory and practical exercise in day-to-day business. HEIs are also called to determine the priorities of knowledge that the industry is requiring according to current and projected needs, aligning the interests of HEIs themselves, with the environment and government strategies.

The constant development of knowledge through research should impact the function of Teaching, offering updated and relevant issues, techniques and tools for learning. Knowledge should not be idle, but helpful in every possible and practical dimension.

The **Extension** function is particularly important for the promotion of product design engineers acting as entrepreneurs, and also for the HEIs. It becomes a means that allows institutions to expand the scope of their impact, while facilitating new revenues from portfolio diversification, offering consultancy, courses, lectures, and training, among other services. By promoting product design engineer's achievements through trade fairs, exhibitions, and other spaces in the community, HEIs might help to make visible the benefits of these professionals to the industry. Interviewees repeatedly stated that HEIs, in their potential as convergence places, are not taking advantage of the many opportunities the campus's infrastructures offers.

Through Extension HEIs must make knowledge built in the academic exercise available through continuous education, facilitating constant updating for the members of the industry. The convergence of different audiences to these Extension spaces promotes and supports networking among all members of the community (enterprises and product design engineers). HEIs are required to have an active role in community integration.

The new identified substantive function, **Support and Integration**, puts HEIs in a position where they need to recognize themselves as articulators, not only of the ecosystem, but also of the different tasks and activities within the other substantive functions (Teaching, Research and Extension). This new function calls HEIs to be third generation educational institutions. Thus, HEIs become spaces that articulate and integrate the community, while being mediators of the relationship between all actors involved in the cultural and creative industry.

This function requires from HEIs promotion and management of partnerships between the different stakeholders in the industry to help networking, while convening experienced leaders and managers that support the growth and development of the industry. HEIs should be centres of convergence of experience, knowledge and resources that augment the growth potential of the industry. They are able to show results that draw attention and interest of other HEIs, partners and supporters, which in turn

provide more experience, knowledge and resources. An example of this would be an increase in projects supported by agencies like the World Bank, IDB, AECI, British Council, local and national Governmental agencies and others alike.
This new function calls HEIs to promote and support success stories (start-ups and spin-offs) that can become a point of reference for new product design engineers and the industry. The experience built by HEIs through these actions, provide them with knowledge and know-how to strengthen the industry value chain. The HEIs are a repository of knowledge and information whose responsibility will always be in giving back to society that knowledge into actions that add value.
All previous statements about the substantive functions of the HEIs suggest a model for the promotion and development of cultural and creative entrepreneurship (including product design engineers among others), appropriate for the context of higher education. The results of this research suggest that HEIs may become agents that enhance and impact the development of the industry, to the point of affecting economic indicators showing prosperity, growth and long-term sustainability of the cultural and creative industry, as long as they develop specific activities according to each substantive function. This, of course calls for reflections upon HEIs' conventional structure, so they can adapt to new emerging challenges and opportunities, while remaining true to their role in society. These findings, in summary, are meant to be, "fresh insight that may lead to useful prescription" [11].

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UTILIZING SMARTPHONES TO IMPROVE THE EFFECTIVENESS OF UNIVERSITY STUDENTS' COLLABORATIVE WORK

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ABSTRACT
With the rapid improvement of technology, the screen size of smartphones is becoming bigger, battery life is increasing and more processing power is available. Smart phones have been regarded as a complement-learning tool beside formal classroom-based pedagogy. Compared with traditional personal computers, the portability of smart phones enable groups of students to work on a common project while not tied to a fixed location. Previous studies have shown that mobile learning provides opportunities for students to learn from within real contexts/situations not tied to a specific location. Mobile learning can also aid in multimedia authoring and sharing. Few articles discuss whether these new features improve the effectiveness of students' collaborative work. The goal of this paper is analyzing the use cases of personal computers and smart phones, identifying suitable tasks for smart phone use, and conducting usability tests that can lead to improving the effectiveness of mobile collaboration. The task performance of college students' collaborative work on smart phone and on laptop will be measured, and students' preferences will also be collected in this study.

Keywords: Mobile learning, collaborative work.

1 INTRODUCTION

As the technology advances, smartphones are increasingly used in students' daily life. Students use their phones not only for making phone calls and sending/receiving messages. They are able to browse Internet, record videos, and entertain themselves. Due to their widespread use, great attention has been paid to utilizing smartphones as a way to improve students' academic performance. Previous research has found that mobile learning seemed to be a good complement-learning tool alongside formal classroom–based pedagogy. It provides students with the ability to learn outside the classroom, to access rich digital resources and to communicate with others ubiquitously [1]. Mobile learning provides great flexibility but is limited by its relatively small screen compared to a laptop. Little study has focused on mobile learning compared to laptop-based learning with respect to group collaboration. This paper focuses on identifying unique use cases for collaborative mobile learning, designing a new mobile application that facilitate collaborative work, and evaluating the impact on collaborative performance.

2 BACKGROUND

Mobile learning has three main advantages: portability, context sensitivity, and instant connectivity [1]. It provides the students opportunities to study at their own speed, the possibility of learning within a real context, working with others on projects, and learning outside the classroom. Mobile learning is defined as more than just learning supported by a mobile device but learning that is both formal and informal as well as context aware and authentic for the learner [3].

Previous investigations have found that fast access to information is an important feature to enable mobile learning. The results of one focus group among college students [3] suggested four main advantages provided by mobile learning: Quick access to information, better communication, an increased variety of ways to learn, and situated learning. Quick access to information included advantages such as receiving emails from instructors, referencing course content online, or the ability to easily search searching for useful information. Communication with instructors or other students was improved as using a mobile device as often more convenient than logging onto a website from a laptop. Avenues for learning were increased through the ease of access to information (such as external media, interactive messaging/chat, and other resources) that allows the student to engage material in a format/situation that is most comfortable. Finally situated learning is enabled by allowing engagement with material within a particular context or environment. Material can be experienced in either real world or classroom type situations that are more authentic to the learner. A different investigation [1] found similar results. In this study three main features of mobile learning were identified. They were ability to access course information, ability to communicate with instructors and the ability to discuss course content with other students.

Technical limitations of devices such as slow processor, network connectivity, relatively small display and awkward input [2] [5] have been cited as issues for mobile learning in the past. Advancements in technology have to some extent addressed these, though some are still cited. Poor input methods such as small touch screen keyboards still pose problems for anything more than small/quick responses. Technology integration, such as applications that do not work as they are supposed to or not working properly with the device hardware also get in the way of effective collaboration and learning. Finally the devices themselves can at times be a distraction, particularly when other applications compete with the learner for their concentration (i.e. incoming text messages, emails, Tweets, etc).

Liaw [6] identified four design principles for mobile learning systems that broadly address these technical and user needs. Mobil learning systems should be: simple, adaptive, individual and communicative. They should be simple because mobile devices have a relatively slow central processing unit (CPU) and a small amount of memory. To encourage students to utilize it in their spare time, in terms of user experience, the system should be easy to operate. Learning activities should be meaningful and customized for individual learners and take advantage of the fact that handheld devices are personal tools. A mobile learning system should also provide adaptively communicative and collaborative functions to facilitate easy communication of digital content to others.

3 DESIGN

The aim of this project was to begin to develop a mobile application to improve student's academic collaboration. The application is based on a social network platform that enables students to join groups, follow people, create, share, and collaborate on contents. It is focused on providing students with the opportunity to explore academic groups (related to specific topics, classes, etc). Once a group is joined students can get updates on group activities, participate in group discussions, follow other members of the group, and build connections. The application will be a mobile interface to an existing browser-based collaboration tool called the Open Academic Environment (OAE). OAE is used for enhancing teaching and learning via social media. It allows users to follow scholars, upload media files, create discussions, and work on collaborative documentation. The goal of OAE is to create a new way for students and faculty to create knowledge, collaborate and connect with the world [8].

The design, development and investigation of this mobile application mock-up was conducted within a Vertically Integrated Projects (VIP) course at the Georgia Institute of Technology. The VIP Program integrates undergraduate students, graduate students and faculty research within a team-based context in order to benefit from the design/discovery efforts of collaborative teamwork [7]. The initial design of the new OAE mobile application consisted defining use cases, gathering user needs and low-fidelity prototyping.

3.1 Use Case

Two specific use cases of the application focused on joining, and following were generated. Joining refers to a user interacting within a group, uploading media files, joining discussions and collaborative writing, such as a study group. Following is passive. Users receive various updates about the group but do not directly interact. These use cases were selected because users need to be able to actively interact with groups (especially if they are strongly interested in it) and also need to be kept up to date on all groups which they have joined whether or not they have a high or low level of interaction with them.

3.2 User Needs

Based on the background information and several group brainstorming sessions, potential features needed to support mobile group collaborative work were defined and grouped in an affinity diagram.

These included features such as group statistics, group information and recent activity (Figure 1). In order to gather more specifics about what users look for when deciding to join a group, an interview was conducted among students at the Georgia Institute of Technology. A convenience sample of 14 subjects (5 male, 9 female) participated. All were industrial design students were offered the incentive of an extra course credit if they participated.

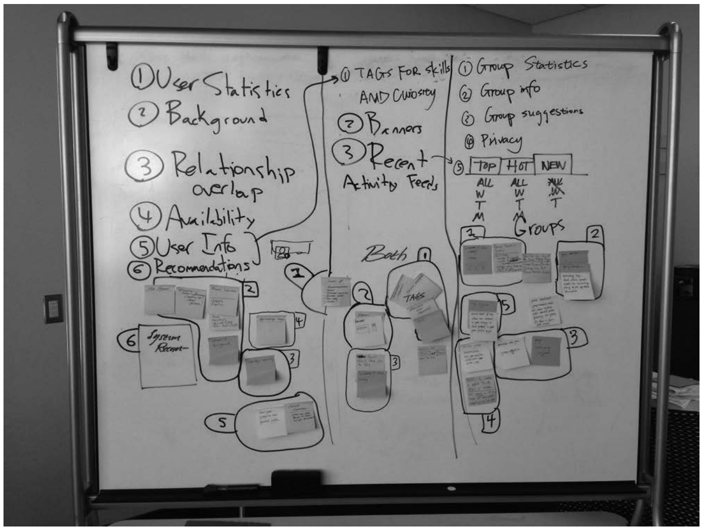

Figure 1. It shows how the function/feature for a group and for an individual user were defined

The interview was composed of three parts. First was a round of interview questions about online group activities. For instance, "Why did you join each group?", "What were you trying to achieve by joining each group?", and "What information helped you decide to join each group?" These questions were meant to gather relevant qualitative information that could be used to help make sense of later data from the test, such as, which information users paid most attention to when they decided to join a group.

The next section of the test was a storyboard depicting the following situation: a student notices a group of interest, uses the mobile app to find the group and examine the profile, and then either joins or follows the group. The storyboard was based on the two use cases (Join and Follow) generated before. Two separate storyboards were used, one presenting a scenario where the student follows a group, and the other where the student joins a group (Figure 2).

The final section was used to measure users' preferences about different features when they consider joining a group. It consisted of a ranking activity. The subject was given multiple cards, each labelled with a different possible feature that a group profile page could display. The subject was then instructed to arrange the cards into three groups listed as 'Very Important', 'Good to have', and 'Not needed'. The frequency of each feature was calculated for analysis.

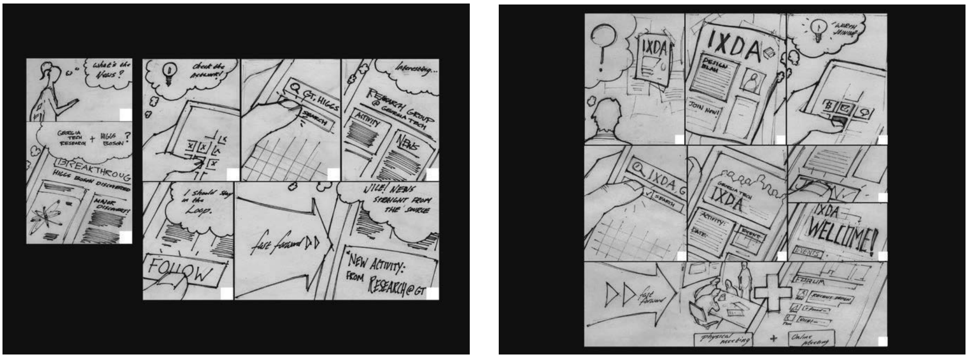

Figure 2. Storyboards showing Joining (left) and Following (right).

The top six most essential features for a mobile app were the “Group Description”, “Activity Feed Ranked by Recency”, “Activity Feed Ranked by Popularity”, “Number of Members”, “Number of Active Members” and “Relevant tags” (Table 1). The least essential features were the “Number of Posts”, “Average response time to discussion posts”, “Number of posts in the past 7 days”, “List of people you have followed who are in the group”, and “Number of files contained in your library”.

Table 1. Users’ Preferences

Feature	Number	Percentage
Group description	14	100.00%
Activity feed ranked by recency	10	71.43%
Activity feed ranked by post's popularity	9	64.29%
Number of active members	9	64.29%
Number of members	6	42.86%
Relevant tags	6	42.86%
Number of posts	3	21.43%
List of groups commonly joined by people	2	14.29%
Number of files contained in Library	2	14.29%
Number of posts in the past 7 days	2	14.29%
Average response time to discussion posts	1	7.14%
List of people you have Followed	1	7.14%

3.3 Prototype

Based on the interview, a low-fidelity linear prototype was created in Axure, a software program that helps designers quickly create wireframes for user testing [9]. The prototype (Figure 3) focused on testing a) browsing and joining a group and b) following an individual person.

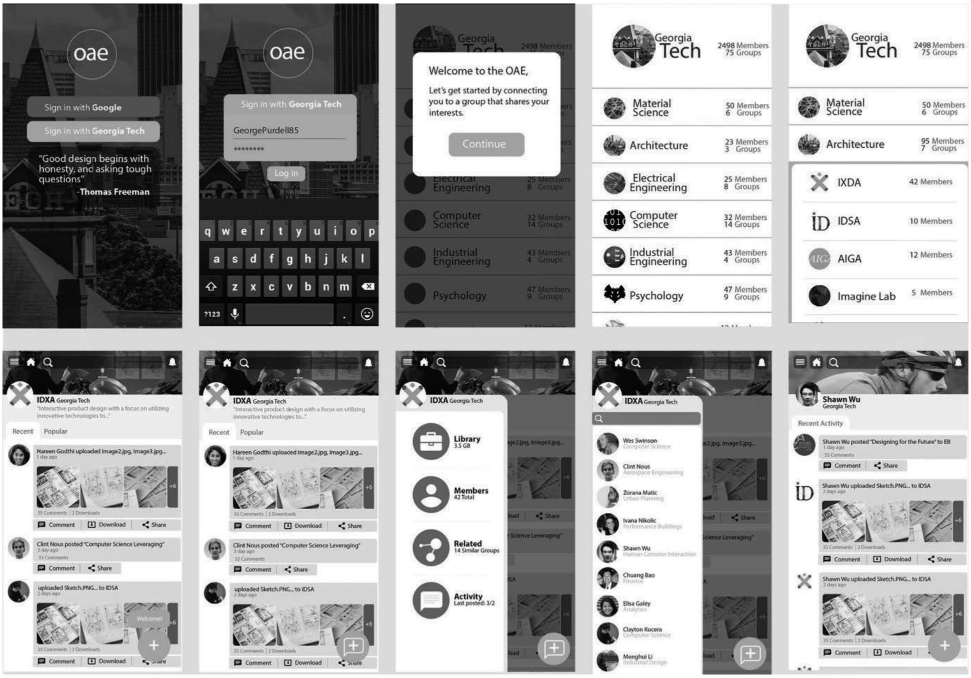

Figure 3. Linear prototype showing the workflow of the mobile application.

4 DISCUSSION

The interviews indicated that students pay a lot of attention to the group description and recent activity of a group when they are deciding whether or not to join. The Group Description is necessary to provide a general idea of what the group is about and its focus. The "recent activity" and "number of active numbers" give an idea about the vibrancy of the group and suggests that students are most interested in being a part of active communities (whether or not their own level of active participation is high).

Some other important attributes of the application were also raised from the interviews. User satisfaction is a key factor that will determine whether or not the application will ultimately be accepted and actually used. A couple of the main contributing factors to acceptance is the functionality of the system and also the level of user autonomy. It is important from the user perspective that the required functionality is present. Missing functionality would obviously add to frustration with the system but it is critical to ensure that the functions actually work well (both with the mobile hardware and the underlying OAE system). Users must also feel like they are in control (have autonomy) and have the freedom to engage with the system in a way that fits their individual needs.

At the time of this writing, the application is still under development and testing. The factors for acceptance will be important factors in evaluating the mobile application as additional functions are added and tested.

There are several limitations to the results presented. The sample size is obviously limited. The students interviewed were all from a single department so a broader range of students from different schools and disciplines will be needed to identify additional needs and issues. In addition, during the interviews, the order in which the information was presented/requested (interview questions, storyboards and the feature card activity) may have lead to subjects giving different answers. For example, when asked what mobile service they used most the majority of the subjects answered Facebook. From that point on, many of the questions were framed using Facebook as a context. Steps may need to be taken in future interviews to avoid this kind of framing.

5 FUTURE WORK

Usability test will be conducted with the high fidelity prototype which is still under development by the VIP team. This testing will focus on examining the intuitiveness of the application workflow, the size and location of the buttons, and overall acceptability and usability of the prototype. Based on the result, the group will further refine the prototype in order to ultimately implement a fully functional application for both Android and iOS based mobile devices.

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Chapter 4

Technology

DESIGN PROCESS AND CONSCIOUS PROBLEM SOLVING THROUGH COMPUTER AIDED DESIGN EDUCATION

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ABSTRACT
With rapidly changing technologies in product development, it is necessary for product design (PD) students to focus on inquiry-based learning in order to adapt to changes instead of simply learning form-giving and model-making skills. This paper seeks to explore how digital model making computer-aided design (CAD) skills can be learned in congruence with these new demands. A case study was chosen to exemplify how a practical training can be used as a tool for self-learning management. Students were observed in a learning situation where they use SolidWorks feature tools for the first time. As an alternative to being guided gradually, by repeating commands presented by instructor, they were encouraged to discover SolidWorks features through modeling a sketch-represented concept. This way of introducing the software features opened possibilities for conscious problem solving. This process led students not only to learn how to use the software effectively but also to understand the applicable value of this tool.
The theory of communities of practice was used to examine students' situational subjective experience in order to evaluate sources of motivation for further learning the software. The results indicate how student efficacy and motivation to learn SolidWorks can increase through tailored learning experiences. Finally, the paper reflects on societal demands and expectations for reeducation where students should self-manage their learning process in both training and productive practice.

Keywords: CAD exercise, conscious problem solving, meaningful learning.

1 PRACTICAL SKILLS AND LIFELONG LEARNING

Teaching practical PD skills through an intuitive problem-solving process is an established practice in PD education [1]. However, as the result of the fast pace of changing technologies and knowledge creation in recent years, new perspectives on learning have emerged owing to the need for lifelong learning and learning through networks [2]. Over the last twenty years, technology has reorganized how we live, how we communicate, and how we learn. Vaill emphasizes that "learning must be a way of being – an ongoing set of attitudes and actions by individuals and groups that they employ to try to keep abreast of the surprising, novel, messy, obtrusive, recurring events…[3]." Because technology develops rapidly, almost half of the skills that students acquire in higher education, today will be obsolete by the time they are employed [4]. According to Friedman, as design education cannot prepare students for the novel technologies of the future that are difficult to predict, it is important that design students develop their competence through inquiry-based learning. Therefore, design education today should place greater emphasis on the design process and conscious problem solving instead of form giving, drawing, and model making [5]. As Swanson claims, "the design students of today will be the inventors of the design field of tomorrow" [6]. Because of these conditions, the goal of educating future designers is to support their abilities in reflective thinking, problem solving, and lifelong learning in order to ensure they can effectively adapt to coming changes and challenges [4].
There is a need to address the fast-changing knowledge and rapidly evolving design profession in relation to learning practical design skills as design education is trying to minimize costs and depart from traditional small-group tutoring [7].

1.1 Digital modeling as a practical model-making skill

One of the practical design skills, digital modeling, has been widely adopted by design practitioners and schools. It has become common because of its ease of adoption and low costs, but it has also been widely criticized because it involves departing from physical experimentation and obstructs divergent design processes with its parametric structure [8]. In recent years, the digital modeling tools have evolved and diversified to various fields adapting to different workflows in order to support creative practitioners producing everything from media to virtual prototypes; such tools have also been adjusted to different phases in the design process [9]. Digital modeling is a process in which a CAD system is used to assist in defining the geometry and visual appearance of design [10]. Digital modelling is generally utilized during the convergent phase of a design process where designers make final decisions through incremental changes by editing and modifying geometry. It enables three-dimensional manipulation of objects in ways not possible with physical tools; it also allows designers to work with more precision and in greater detail. One of the main characteristics of CAD systems that appeals to designers is that they offer the possibility to make photorealistic renderings quickly [11]. Experienced design practitioners are adopting this tool in their workflow, learning the new ways to use it over time through experimentation; as a result, the role of CAD in the design process and in various types of software is changing very fast [9]. However, the downside of CAD systems is that most of the software used by designers is not necessarily compatible with a design workflow and is used and learned by design students completely separate from the design process, which can result in lack of interest or a difficulty to adopt it [12].

1.2 Teaching CAD systems in the context of design practice

In practice, CAD is taught in different scenarios. It can be taught by software distributors who organize courses as a course in design study curriculum. It could also simply be left to students to implement it in problem-based learning design projects. In these projects, design students independently discover how CAD can be implemented in the design process. Even though strategic use and teaching of CAD is discussed and strategies are proposed [13], it has not become common practice in design education. The way the future designers are introduced to CAD can affect the way they structure their workflow [14]. This can have implications for how design students manage future design problems that are not possible to predict.

The intention of this article is to put the CAD learning process in perspective through the production of design practice and its meaning for learning design skills in general. There is a need to examine the role of CAD teaching in design education outside the usual tutorial setting. The article therefore discusses possibilities for design students to learn adaptively so that they can translate this way of learning to other settings. This is especially important in the context of very dynamic and changing design practices, where conscious problem solving, as opposed to intuitive problem solving, is crucial. The intention is to "increase capacity of a learner to form connections between sources of information, and thereby create useful information patterns" [2] instead of using rich experience to intuitively solve problems [15]. As CAD is replacing traditional skills as a way of generating, analyzing, and collaborating in a design process, it is important to discuss this skill in the context of problem solving. The research question is therefore as follows: How can a CAD course enhance conscious problem solving and design process?

2 THE TEACHING PERSPECTIVE

As the case study describes the classroom setting, the theory of communities of practice [16] is used to analyze the communication between students and to describe the competence-acquiring process through the exercise. The problem of competence is therefore central to this article as it is argued that generative and practical skills are not suitable for future PD competence [5]. Because self-teaching and critical reflections are important for the problem setting of this article, self-organization is discussed as the ability of a learner to define what is important for the problem-solving process [2]. The instructional side of the course was discussed through instructional theories to comprehend how to teach in order to contribute to the desired competence [17].

In order to study how CAD can be learned in congruence with the design process, the case examined here is from an introductory course to SolidWorks CAD software at Institute for Product Design, Oslo and Akershus University College of Applied Sciences [18]. The case study was needed as an exploratory tool in order to understand a real-life CAD exercise situation and its context. The case was relevant because students need to cover the basic software skills in order to be able to complete their future design courses. In order to research the social and physical setting as well as the students' behaviors and activities, participant observation [19] was used as a method to collect data for the case study. The archival studies of CAD exercise results were used to confirm the different approaches students took to solve the problem. The course manager was interviewed [20] for description of the course plan and implementation. This case study was chosen because of the bi-product of the CAD exercise; i.e., open-ended problem solving that is in line with PD methodology.

3 THE CASE OF AN INTRODUCTORY CAD COURSE

The intention of the introductory course was for students to implement CAD as part of the design process dynamics. The course was built around SolidWorks as an intervention tool such that objects are transferred from reality into the virtual world and then manipulated in order to be tested through rapid prototyping in reality. The digital tools should thus be learned in the context of design intervention rather than design creation. This course was isolated and taught separately from the rest of the subjects for the PD students, who were in the first semester of the first year of their bachelor studies.

The first part of the course emphasizes reverse engineering of an existing physical object where students had to analyze an object and its parts in advance before then measuring and remodeling it. The intention was for students to acquire instant insight about not only how well they are using software features but also how well they understand the form and construction of a given object. The intention was also that the new PD students who do not have any experience in form-giving learn to analyze and generate forms and constructions through the same set of tools.

Figure 1. The sketch on the left and the modeling outcomes on the right

The next part of this assignment was even more complex as students were given a design sketch of a bar stool (Figure 1) to interpret and then generate a virtual model out of it. This sketch was not previously tested through a CAD or physical model. The representation of the stool proportions differed from the written dimensions as the sketch was a representation of the sketcher's imagination and the dimensions were taken from the ergonomic handbook. Here the intention was for students to interpret the sketch that somebody else generated and apply their findings through a set of software features. In this exercise, they did not have any physical objects so they had to imagine it. No additional instructions or guidelines about how to analyze an object were given to students. The exercise was presented as training in the use of software features. The students were instructed to finish their virtual models to be used as production documentation, which therefore should have a large degree of detail, including materials, fasteners, and needed mechanical details. Students were also instructed to conduct analysis on the center of mass in order to evaluate the actual usability of the stool in connection to materials. As the exercise progressed the students started to notice the discrepancy between the visual representation and the written measurements on the sketch, and the following questions arose, as the course manager explains:

> "As this started to become apparent to some of the students, I stuck to the initial premise and refused to answer questions related to design aspects of the assignment. I assisted in purely technical issues related to the software, but they were on their own in regards to the design contradiction."

All of the students noticed the discrepancy between the visual representation and the given dimensions at the end, but the students who had the most experience with software features noticed the mistake first. Students started to discuss among themselves what the right thing to do was. They tried as best as they could to answer what was expected of them in the task and find the right way to interpret the sketch. Some opened discussions around ergonomics of the barstool, some constructional, and some aesthetical. Some of the students consulted the Internet to check the typical measurements for the barstool. The results were comprised of those who followed the dimensions exactly; those who ignored the dimensions and tried to recreate the visual intent of the sketch; those who tried to come to a compromise between the two; and lastly those who created both models.

The feedback from the students for this type of assignment was positive. The tedium of learning CAD tools and methodology was overcome by the necessity to solve the problem and utilize design processes. The CAD skills were the main focus of the exercise, but in a way that they might be used in practice, therefore avoiding the more traditional tutorial or a "click-this-enter-that" exercise.

4 CAD EXERCISE AS A MEANINGFUL LEARNING PROCESS

Wenger [16] describes competence as a direct result of a social history of active negotiation of meaning within a community of practice. The meaningful learning thus happens through participation and reification interplay that creates the memory of a community of practice. Participation relies on activities, conversations, and reflections. On the other hand, reification concerns physical and conceptual artefacts: concepts, methods, documents, links to resources, and stories. Reification literally means "making into an object." Because Wenger [16] believes learning occurs through practice, the CAD problem-solving exercise may therefore be seen as a search for meaning that is alive and renegotiable. In the context of design process, reification can be seen as generative, while participation can be seen as an exploratory part of the design process.

In the case study, the concepts of participation and reification can be seen as the students start to actively discuss what the right way to model the barstool is as they are building a digital model. In an attempt to accomplish a reification task, and in the absence of outside intervention, participation began with their need to negotiate what is the right competence for solving the problem. They returned to a reification process by applying their findings to a digital model. The case study also shows how students negotiate meaning in alignment with their "regime of competence" as they struggle to fulfill the task the way it was posed to them. The "regime of competence" is characterized as a set of criteria and expectations by which a community of practice recognizes membership [16]. Students are discovering that they need to operate as both software users and design constructors in order to be part of the community of practice. This ability to spot, grasp, and intuitively adopt new regimes of competence might be crucial in the context of rapidly changing design practice.

5 TREATING CAD AS A REIFICATION SKILL

As the rapid evolution of the design discipline is taking place, it can be assumed that practical design skills are not a priority for design education, as we cannot possibly know what the future design competences are going to be [5]. In that sense, CAD as a competence can be criticized for both the lack of potential for a divergent design phase and for the ease with which it can be outsourced to digital modelers [11]. On the other hand, traditionally, design is seen as abstract, associative thinking for problem solving that happens through a reflection-in-action process of trial and failure [21]. The theory of communities of practice [22] offers an alternative view on how design competence is evolving because it sees the production of design practices as an output of a social learning system.

Seen from this perspective, practical PD skills and activities are nothing more than reification processes needed for negotiating meaning and production of practice. They are not to be seen as the goal but rather as the agent of creating a collective history of learning. In the case study, the exercise is set up so that students have to negotiate the meaning of the problem. They are competent negotiators

of meaning [16] rather than bearers of knowledge who are able to reframe contexts [15] or define critical questions motivated by curiosity [23].
In the context of a rapidly changing design practice, Wenger would argue that students' ability to adopt new regimes of competence and their ability to negotiate the meaning of the problem through the interplay of reification and participation are both crucial.

5.1 Implications for learning CAD

The case study shows how the CAD taught in a social context can bring new qualities to PD education. In contrast to tutorials guided by a supervisor or the software itself, these CAD exercises are put in the context of collective learning. Although the response from students was very positive, there is a need for more research about how these exercises can impact the intended learning outcomes that were clearly not only software feature-oriented. Seen from the perspective of constructive alignment [17], there are some values that can be analyzed in the CAD exercise described. As the constructed object defines the exercise, it is foreseeable how much time it will take to finish it. The work is directly related to a PD activity by students, which also seems comprehendible and conductible. The task presented in the beginning is clear and feasible. Because it seems to have a closed-ended solution, the skill level seemed to match the challenge level [24]. These are all values that might increase what Biggs defines as extrinsic social achievement and intrinsic motivation [17]. As all the students delivered their exercise tasks as demanded, it can be concluded that the software learning outcomes were obtained. The fact that all the students noticed the discrepancy between the representation of the bar stool and the dimensions indicates that conscious problem solving was activated. Some students have also engaged in the design process as an intended learning outcome, as they were actively discussing and searching information in order to solve the problem and then testing that information on their model.
Biggs claims that motivation and deeper levels of understanding arise from fascination or intrinsic interest when a student already knows about and is involved in exploring the topic. He explains how good students are already oriented toward inquiry-based learning. In contrast, beginners and students who struggle have difficulties to recognize the value in learning tasks and to expect success when engaging in learning tasks. A carefully planned CAD exercise can be a potential intervention to address such difficulties, as it can spark participation through a reification process that seems defined and predictable, yet gives students a framework to ask questions. This framework is useful as it puts students in a situation to evaluate aspects of the problem and search for needed information.

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VISUALISING WORKPLACE DESIGN

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ABSTRACT
Design is a learning process and the use of prototyping activities for the sake of learning increases the design thinking, i.e. the dialogue and feedback on ideas. Hence, representations ranging from sketches to different kind of models and animations are recommended to be used as prototypes to mediate user needs and to support communication within the team. Low-fidelity prototyping enables rapid visualisation of ideas, reframes failures into learning, generates perceptual progress and supports creativity. In product design, different visualisation techniques are used to generate and communicate ideas since thinking visually is seen as necessary for innovation.
This paper describes the work of developing a course where you combine the task of workplace design with traditional industrial design visualisation methods like sketching, model making and 3D computer aids. By using the knowledge and experience from product design and incorporate it into workplace design, a process where all parties contribute in new ways could be achieved.
In the course the students start by performing an individual investigation of the present research front for production visualisation by summarizing and analysing a number of scientific articles. A work place design project was then performed where exploratory, explanatory and persuasive visualizing techniques were implemented. Through a creative and constructive collaboration across disciplinary boundaries, Industrial Production Environment and Industrial Design, we have created and implemented a course in an area that has been lacking in our Master Program.

Keywords: Workplace design, layout, visualization, communication, participation.

1 INTRODUCTION

The industrial companies' ability to continuously change and develop work places and production systems is an important prerequisite in order to compete on a flexible and international market. Rapidly changing market demands call for manufacturing systems to be continuously developed. This requires flexibility and effective redesign processes involving contributions from personnel across an organization. Involving stakeholders, such as operational staff, in the design process is often crucial for achieving successful results. Personnel working in the production system on a daily basis generally have a genuine understanding of the system and their knowledge is important to incorporate to the design process. Active participation of stakeholders also simplifies the work to establish and gain acceptance for the proposed changes.
Proficient communication between stakeholders is essential for enhanced user participation. There are essentially three ways to communicate; verbal communication, written communication and the third and final communication path is visual. In the field of product design, the techniques of visual communication are very well developed and frequently used throughout the whole design process. Within the field of work place design, visualisation aids are not widely spread, especially when it comes to the early phases of the work place design process. Visualizations used in the design process of manufacturing systems and work places are often limited to traditional blueprints, different kinds of manufacturing simulations and 3D visualisations to present final design proposals.
As Håkansson et al. [1] states, it is of great importance to create a common mental model of the task at hand and to choose the correct way of communication depending on the type of task. Communication is meant to be used as a tool to create contacts, transmit ideas, influence and develop. It can also be used for making progress visible and provide information necessary to proceed, when progress appears absent [1]. Visualisation increases the opportunity for all parties to actively participate in the development process and is a prerequisite for user-driven processes. A transparent process also

increases the motivation of the employees and the usage of visualisations creates improved affinity among the personnel across the organization [2].

Throughout the design or redesign process of a work place or a production system, from early ideas to the implementation phase, there are several situations when visualisation tools are suitable and can help to improve the quality of the process [3]. Various visualisation techniques perform different functions depending on when and for what purpose they are used during the design process [4]. As an example the planning part of the process can be accelerated by using visualisations, partly because the visualisation technique helps to minimize the risk of unnecessary misunderstandings [5].

Industrial simulations are a common tool to visualise the actual production system. Simulations, however, only provide an abstract view of reality which often makes them hard to understand for anyone other than experts in the field. The usage of simulations can therefore be limited when searching for enhanced user participation. A 3D visualisation of the simulation can help to present the results of the simulation in a way that makes it easier for all stakeholders to be involved and so decisions can be made easier [6]. A method of how to build a virtual factory by integrating discrete event simulation with visualisations in 3D, which makes the simulation much easier to understand and thereby enables user and client participation, is presented by Zhong and Shirinzadeh [7].

A relatively new visualisation method is 3D scanning. By using a combination of CAD and 3D laser scanned as-built data of the current system and facility, photo realistic visualisations of the work place can be made. The method has proven to be a useful tool in the early phases of manufacturing system redesign when it facilitates understanding of the future system [8].

Although most of the research done in the field of visualisation of production system is focused on digital visualisations, simple hand sketches and physical models often have the potential to fill a substantial role in early project phases. To support communication and understanding in cross-functional project teams different kinds of artefacts can be used. An example is a successful study where artefacts such as a layout game board and documents with ideas and requirements were used [9].

Rapidly changing market demands increases the need for efficient design processes with participation from personnel across an organization. Even if the research in the area is still limited most appear to be in agreement when it comes to the benefits of visualisation to ensure a good user and client participation.

If we look at design as a learning process, the noun *prototype* and the verb *prototyping* spurs an interest [10]. A prototype can be interpreted as a representation of a final product, just lacking some minor features. In such a case the intended use of prototypes is to communicate and verify the final design. Only applying prototypes of these kind constraints the communication in the team, since prototypes that appears to be finished decreases the dialogue and feedback in the team [11]. The use of prototyping activities for the sake of learning increases the design thinking, i.e., the dialogue and feedback on ideas. Hence, a wide range of representations ranging from sketches, drawings to different kind of models and animations are suggested to be used as prototypes to mediate user needs and support communication in the team [12]. The application of this kind of low-fidelity prototyping makes it possible to rapidly visualize multiple ideas, and allows reframing failures into opportunities for learning. It also generates perception of forward progress and supports the team's creative capabilities [13].

Sketching is a low-fidelity prototyping method, and the concept of sketching can be stretched further then just using pen on a paper. Any medium could be used; clay, paper, chairs, body postures, 2D- or 3D-modeling software, etc. The ambiguous and unstructured characteristics of sketches results in reinterpretation [14], and sketches are even seen as critical for being able to capture the ambiguity inherent in design activity [15]. The classical engineering tools, i.e. CAE, CAD, data- and protocol analysis etc., are not suited for prototyping activities since they are time consuming and therefore limit iteration. They also lack the ambiguous character of sketching activities; they are precise, fully envisioned and give little room for free interpretation. They are more prototypes than prototyping mediums. This limits the creative freedom since the act of combining and restructuring, that sketches facilitate, is inextricably linked to creativity [16].

In the field of Product Design a wide range of visualisation techniques has been used for a long time to generate and communicate ideas and solutions between users, designers and stakeholders in projects. Being able to think visually is also seen as a necessary skill for the development of innovative ideas [17], and low-fidelity prototyping supports this. By tapping the knowledge and use the experience from the product design field regarding visualisation techniques and incorporate it into work place design, a more effective development process where all parties can contribute in new ways could be achieved.

2 PEDAGOGIC APPROACH

As stated above, it is identified that using visualisation methods, common within the field of product design, is rare in workplace design. To start to deal with this, the need was analysed and discussed with people from departments at the university working with workplace design and product design as well as with people from the industry working professionally with production development and workplace design. The main issue was the lack of understanding and communication in the early stages of the design process in order to improve efficiency and precision when designing a new workplace. Looking at the field of product design, one uses various kinds of visualisations to overcome this communication barrier as well as for making the design process more efficient and exact. To implement this approach when designing the workplace would improve that design process significantly. The outcome was to create a new course for the fourth-year students where visualisation and communication would be the central parts.

The intended learning outcomes (ILO:s) [18], are to make the student understand how to make use of existing skills, apply this into a new field and to teach the students new ways of visualisation suitable for workplace design. The course content was spread over a number of fields motivating a cross functional teaching team where cognition and communication was covered by Engineering Psychology staff, workplace design by Industrial Work Environment staff and visualisation by Industrial Design staff. The task was to provide a basic understanding of communication and how people perceive and process information in order to make the students understand how and why to choose a suitable way of communication. It was also to develop a knowledge of workplace design including proper terminology, work safety and logistics, and finally to introduce a visualisation thinking approach to the students throughout the design process.

To achieve this, the course was created as a project based course combined with theoretical lectures and assignments parallel to the project. To reach Biggs [19] third level of teaching, how to make the students involve themselves more in the learning activities, the results throughout the course were subjected to peer review where other students evaluated the level of understanding in the communication approach chosen based on previous theoretical tasks in the course.

3 RESULT

The tangible result from this process was a new 7,5 credit course called "Production Visualisation". The main purpose of the course was to bridge the identified gap when it comes to communication in early stages of workplace layout design by implementing accepted and established ways of visualisation from the product design field in order to make ideas and workplace concepts more tangible during the development of a new workplace design.

To achieve this, the course was designed to contain an assignment of designing a workplace, in this particular course a tyre shop. During the design process, the students had to use different kinds of visualisations in order to communicate their ideas amongst themselves as well as with the teaching staff. Throughout the course, lectures on workplace design and visualisation techniques were held in parallel with the project.

Initially, a task to make a survey of the state-of-the-art on the research field was given. Together with lectures on communication, cognition and mental perception, the students were to write a paper on the field and how the theories were handled in current research on visualisation in workplace design. This gave the students a good theoretical base to start their design task from.

The design task was to design a tyre shop from scratch. Some basic data was given, e.g. what different functions and areas is to be included in the tyre shop, what capacity does the tyre shop need, what storage area is needed, etc. The students were divided into five groups according to the identified and stated function areas; Reception, Workshop, Storage, Tyre hotel and Staff area, and started with identifying the functions and needs for these areas. Visits were made to local tyre shops to get a view of how it works there and to get information from interviews and observations.

Next step was to generate ideas on how to design the different areas, each group concentrated on the area they were given and visualised their ideas with handmade sketches. Figure 1 shows examples of sketches from one function area, the workshop.

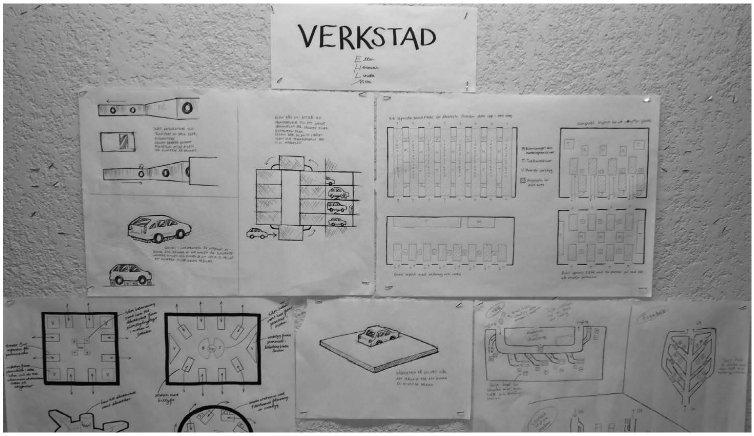

Figure 1. Sketches from Phase 1 (“Verkstad” = Workshop)

The ideas could be on any level, overall schematics as well as detailed design of specific solutions. The aim was to build a wide range of ideas that the whole class could use as inspiration and input for ideas in the later stages of the project, so the focus was more on quantity than quality, and novelty was endorsed. After this phase, the sketches were posted on a wall and the groups were asked to analyse and explain each other’s sketches to see if they were understandable and self-explanatory. These sketches then became everyone’s property because the course changed from group work to individual work and each student was supposed to design a full layout of the tyre shop.

The next phase was to choose and develop ideas so they could be put together to a full concept. The students were asked to present two distinctly different layouts each and they could be visualised either by hand sketches or with sketches/plans made in the computer. Figure 2 shows an example of such a layout.

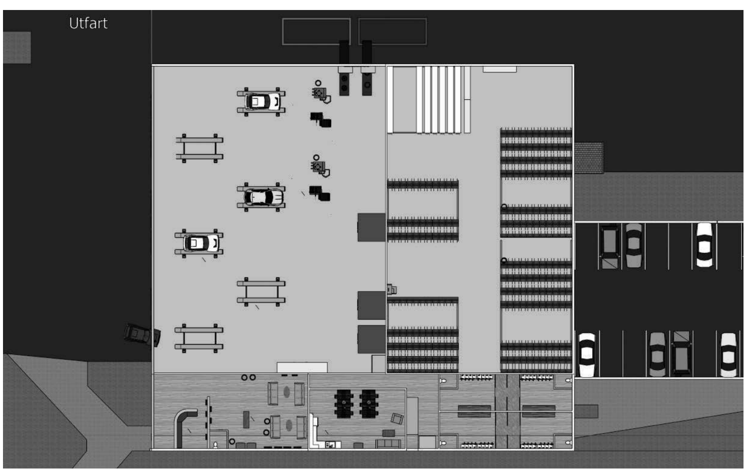

Figure 2. Layout of Tyre Shop

During the presentation of the layouts**,** fellow students as well as the teaching staff were giving feedback on the actual workplace design as well as the type and quality of the chosen forms of visualisation.

The final phase was to choose one of the designs, or a combination of the two, and develop it further in order to be able to present the design concept for an imaginary management group consisting of the teaching staff. The students could use previous sketches and layouts but were obliged to create a 3D animation using Google SketchUp. Figure 3 shows a screen shot form one of the animations.

Figure 3. Screen shot from 3D animation of workplace design concept.

The choice of Google SketchUp was mainly due to efficiency. The purpose of the course was not to learn new advanced software but making the students apply visualisation techniques in a new way. By using Google SketchUp, the step to start creating 3D models and animations is very short; hence the students can concentrate on workplace design and proper visualisations. A short introductory lecture on Google SketchUp was given to start the students up but the main responsibility for learning how to use the software was with the students.

4 CONCLUSIONS

The key factor when designing this course was the formation of an interdisciplinary team of teachers. Teachers from the departments of Industrial Work Environment, Industrial Design and Engineering Psychology were represented and the course was developed and designed in an interdisciplinary collaboration within the team. The configuration of the team satisfied the need for relevant areas of expertise such as production layout design, user participation, visualisation, communication and perception. A conclusion is that this configuration of the teaching team was necessary to achieve the objectives of the course.

Another conclusion is that it was very stimulating for student creativity to use different kinds of visualisations throughout the development process.

The course is focusing on how different techniques of visualisation can be used in various stages throughout the design process. In autumn 2014 the course was successfully given for the first time and the response from the students was definitely positive. Although there are parts of the course that still can be improved, it is already evident how the course increased the quality in subsequent project-based courses where students, in collaboration with manufacturing companies, used their skills in redesign projects.

5 DISCUSSION

Reflecting on the course it feels like the objectives are fulfilled. The students have learned to use prior skills in a new field, they have learned new ways to communicate visually and they have gotten a deeper theoretical knowledge regarding why and how to communicate when designing a workplace.

As mentioned above, there is already evidence that the students use these visualisation tools in later courses and compared to results from previous years in these later courses, the use of better visualisations improves the results significantly.

The students have been participating actively in the development of the course with feedback from their point of view. This has been very helpful when looking at the extent of the tasks and identifying parts of the course that could have been designed in a better way. This has also been taken in account when making necessary adjustments for the next course in September.

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EVALUATION OF FLIPPED TEACHING METHODS FOR COMPUTER AIDED DESIGN

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ABSTRACT
'Flipped teaching' or 'Flipped classroom' strategies offer an alternative pedagogical approach to traditional classroom teaching. These inverted methods provide a more engaging learning environment, allowing practice and application to occur inside the class rather than outside. Market conditions, increased student numbers, limited resources and classroom space can put particular strains on computer-based activities such as Computer Aided Design (CAD) tutorials. As such, CAD is a critically vital tool for engineering and design students to learn, practice and use in projects. However, tutorial time restrictions, teaching availability and expertise often limit how much a student can achieve, and how much they can learn in the classroom. With changes to modern higher education providing drivers for new teaching methods, modern CAD packages may enable flipped teaching in the form of web-based learning, video-based tutorials and step-by-step activities. This paper explores these technology drivers and enablers in detail, as well as considering existing or potential barriers. Existing literature of flipped teaching in the field of design and engineering have been reviewed for best practice, as well as strengths and weaknesses of applying flipped methods to CAD. Fundamentally, the paper investigates the potential of flipped classrooms in engineering design and how CAD teaching and student practice can be improved. It explores the embracement of new learning technologies and environments as well as engaging with online and vendor-produced learning resources.

Keywords: Computer aided design, flipped classrooms, technology.

1 INTRODUCTION

21st century higher education faces new and emerging challenges. In the UK, 2015 heralds the uncapping of student numbers which aims to “improve social mobility and raise economic performance”[1]. What impact this will have “remains fuzzy”[1]. UK institutions have looked to Australia (who made the decision to abolish caps in 2009) to learn of the potential impact of these changes. Evidently, “Universities started enrolling above their caps to grab market share”[2] and with the significant rise in student numbers “had to look for efficiencies in their teaching and learning methods. Class sizes have grown, but online learning and flipped classrooms are also on the rise”[2]. It appears with such challenges, technological opportunities present themselves. With the prospect of packed classrooms and limited resources, ‘Flipped teaching’ is considered a superior hybrid of traditional lecture approaches and online, distance learning approaches [3]. Flipped classrooms are known for swapping traditional lecture content with online videos and study materials, allowing the physical interaction to be more focused on discussion and teacher-student engagement. Whilst universities can build high capacity lecture theatres, it is already proving difficult to accommodate students into computer based lab classes. Alternative solutions, such as flexible, online working and Problem Based Learning techniques have been sought-especially as the student cohort may easily exceed the number of available workstations [4]. Such problems arise with CAD teaching, with nearly 300 students to teach (and a computer classroom with 48 PC’s), CAD tutorials need to be repeated six times to teach the cohort in one semester. Each tutorial runs for three 2-hour sessions equating to 36 teaching hours of three academics. The CAD tutorial is three times longer than any other lab class in the unit timetable and the most repeated. With the potential of rising student numbers this problem will only get worse and as such may be the perfect environment to consider flipped teaching methods.
The flipped strategy would seek to reduce timetabled classes, by pushing lecture material upfront, online and getting the students to do activities before class. This ultimately would make potentially

shorter classes more productive, engaging and interactive. Furthermore, due to timetabling, the CAD tutorials are spread between two Mechanical Engineering and Electrical Engineering units (ME10001 and EE10170), both of which do not align themselves well to the aims and learning outcomes from the CAD classes as the units focus on lab report writing and experimental skills. Ideally, it would be beneficial to teach CAD in a condensed format in a more appropriate unit. The key aim of the class is to introduce students to CAD (in the form of solid modelling), with simple design tasks using CAD being the learning outcome. After a 10-15min introduction presentation, the tutorial class utilises online step-by-step part, assembly and drafting tutorials provided by the CAD software, supplemented by bespoke exercises that students complete with basic hints and tips provided in the worksheet. When observing the class, some students struggle to complete the first tutorial within the allotted 2 hour session. It is expected that students complete any remaining exercises in their own time before the next session. However, this is an activity conducted outside class and there is little evidence to show that students complete these activities well, or at all.

2 LITERATURE

Although substantial literature on flipped teaching exists (mainly from the US and Australia), it appears that very little can be found in the field of STEM education according to M.Redekopp et al [5]. The University of Southern California paper primarily focuses on strategies and tools for the most effective model as well as learning outcomes of the participants-all within a computer engineering context. Some core principles of flipped teaching are identified, such as improved interaction in prohibitively large class sizes. The identification of active learning opportunities for students (allowing them to work in their own time to their own goals) [6] and the use of learning technologies (such as online videos) were discussed. Several previous works were investigated to establish best practice. For example, a Matlab course at the University of Wisconsin-Madison using the eTeach system [7]. This provided a computer-based engineering context to draw upon. Contrary to the aims and learning objectives with CAD, the Matlab course focuses on the use of the software to solve engineering problems with a strong focus on mathematics and equations (there is a lot of detail in this area). What is desired from the CAD classes, in contrast, is competence in using the software and the enhancement of engineering design and creative skills. Nonetheless, 66% of the students at the US University believed that flipped teaching had a positive effect on their learning. M.Ronchetti's paper [8] focuses on the merits and student perceptions of video lectures versus traditional lectures. There is some STEM context in the form of C++/Object Orientated Programming but it does not delve into the detailed format of the classes' structure, aims and learning objectives. Although 70% of the students surveyed responded well to the use of video lectures, and 90% agreed/strongly agreed that the flipped teaching method allowed better understanding and participation; a key conclusion is that video is better utilised for creative and non-conventional uses.

3 EXISTING PRACTICE & TECHNOLOGIES

Outside of academic papers and journals, one can find the use of educational video lectures within Panopto and Youtube. Panopto is a well-established video platform for many businesses and universities, and can be used for class-flipping and online/long distance learning (for example, MOOC's) as well as capturing traditional lectures. Youtube, on the hand, is an open video platform used by individuals, business and education. Youtube, in comparison to Panotpo, has the potential to be more engaging with younger students. For example, a video lecture on CAD, by Dr Anoop Chawla at IIT Delhi [9] uses Youtube and other free online video websites to good effect. However, the lecture content focuses on the mathematical background of CAD (Polyons, Transformations etc) rather than practical tutorials in CAD design. It is also a traditional lecture capture, and does not embrace any flipped techniques. For practical tutorials, CAD vendors can supply their own material in video format (including Youtube). For example, Siemens PLM provide SolidEdge and NX CAD tutorials and demonstrations as part of their Academic Program [10]. There are resources for not only students but educators (in which pre-prepared tutorials and CAD models for College and University are supplied). This not only includes Youtube videos and step-by-step web activities (which can be viewed within the CAD environment) but also self-paced learning activities which provide questions and options to test the CAD user's knowledge and technique as shown in Fig. 1.

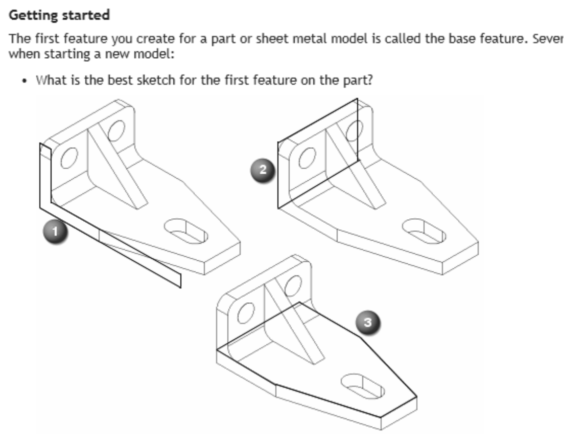

Figure 1. An example tutorial, testing CAD knowledge, from the Siemens PLM website

PTC (who provide Creo and Windchill) also have an Academic Program [11] as well a PTC University Learning Exchange with introductory, intermediate and advanced level video tutorials. Dassault Systems (providers of Solidworks) have an extensive range of teaching resources, demos, Youtube videos, screencasts as well as a video library from Forum users [12]. Autodesk provide a range of web-based guidance and workshop materials based on discipline [13]. Rhino also provide in-depth video tutorials for surface/freeform modelling [14]. It seems that industry CAD vendors have already embraced techniques found in online and long distance learning. However, what could possibly encourage (or discourage) Universities integrating these resources into a flipped classroom?

4 METHODOLOGY

From literature it seems appropriate to engage with students and obtain some feedback on how they feel flipped teaching methods can enhance their learning. An open survey was conducted with a group of students participating in the CAD sessions (a relatively small cohort of 53 students-of which 30 responded to the survey). The multiple choice questionnaire allowed students to rate their satisfaction of the current method of CAD teaching and to consider their potential learning enhancement with flipped and fully online techniques. To evaluate flipped teaching in CAD (and considerations for future planning), a SWOT Analysis was considered; often referred as a SWOT Matrix. Both questionnaire and SWOT analysis are detailed in Fig 2.

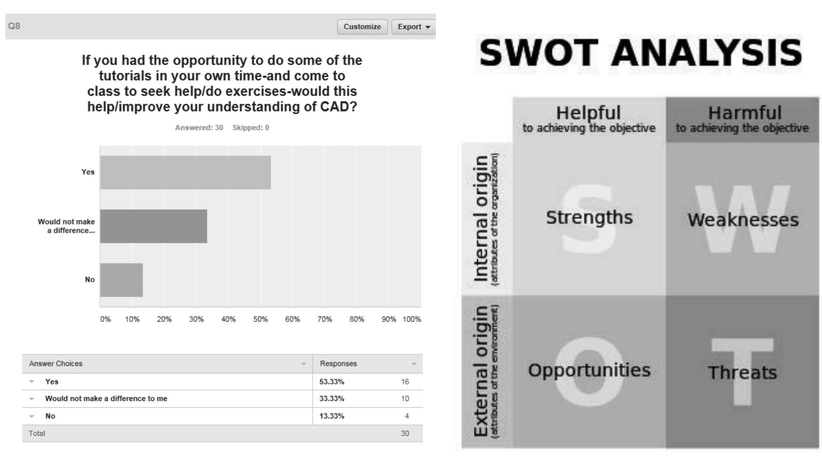

Figure 2. An example of the online student questionairre and SWOT analysis

This planning methodology will consider Strengths and Weaknesses of flipped teaching techniques in the context of academic learning as well as Opportunities and Threats that may present themselves externally (for example, technology changes or CAD vendors). It is hoped that student feedback will offer insight and more rigour into the method. First of all, let's discuss drivers and barriers that must be enabled and overcome.

5 DRIVERS & BARRIERS

From the outset of this paper, the drivers for flipped teaching methods seem clear. There are significant changes to market conditions and student numbers that warrant more efficient approaches to teaching. There is a desire for more engagement, interaction and meaningful activities. This also includes more of a push towards lecture capture and online assessment and feedback. By embracing these methods in more STEM (Science, Technology, Engineering & Maths) related subjects, the more of best practice can be disseminated within the field of Engineering and Design. Another driver is that many students now have access to mobile workstations and can download software for their studies (including CAD) with greater ease. Students now have the capability of working remotely outside of class. The use of online videos for educational purposes is another key driver, and a core technology for successful flipping; having ready-made CAD learning resources to hand helps enable this. Having said that the main barrier appears to be technological, but as indicated in M.Ronchetti's paper [8] video capturing technology has come a long way in recent years. Panopto is well established in many institutions and can be integrated into Virtual Learning Environments such as Moodle and Blackboard. It appears that this barrier has almost been overcome.

6 STRENGTHS

One strong point in adopting a Flipped Teaching approach in the context of CAD is that students could view the introduction lecture as an online video and work on the first tutorial (which is already web-based) allowing time to work on bespoke exercises and activities in class (monitoring their progress in-class rather than out of class). One such activity could be do allow the students to construct a part model prior to the session, and use the session time to show them how to create draft views (necessary for their assignment and project work). Another advantage of this method is that students would be able to work on the step-by-step web-based tutorial at their own pace, in their own time, promoting active learning. However, in context, this would be beneficial to bring all students up to the same level prior to the tutorial (stronger to any learning enhancement) as although 57% of the students who responded to the survey indicated that they would be happy doing CAD tutorials in their own time (mostly using their own workstations), only 47% felt that learning CAD at their own pace would improve their learning outcome. The flipped teaching method does have merit over a 100% online course-as 62% of students indicated that a fully online CAD lab would not improve their understanding. In contrast, a flipped approach (hybrid of online/tutorial class) was supported by 54% of students (with 33% for indifference and 13% non-support).

7 WEAKNESSES

One weakness when adopting a Flipped Teaching approach is managing a tutorial class where not all the students have completed the prerequisite work. The students in the survey were asked to rate their potential success in completing a CAD tutorial before class (with online videos and support). 56% of students believed that they would attempt the tutorial, but would require help in class with problems or completion. Only 18% believed they would not be able to complete the tutorial in their own time and 26% would aim to complete the tutorial prior to class. This would indicate that potentially up to 11 students in the class would fall foul of the Flipped Teaching method, with a majority (around 30 students) requiring assistance to complete. Therefore, it's likely some class time is required to complete the tutorial. Ways of dealing with this include JITT (Just in Time Teaching) methods, which can give teachers the power to modify class content based on the prior knowledge of the class. Completion of activities can be logged via a VLE (Virtual Learning Environment), perhaps comments to the specifics of problems found. From there the instructor can provide the appropriate information and support. Nonetheless, 82% of students would likely have a head start, allowing completion of further CAD exercises in class. There are also additional workload and the skillset of the instructor to consider, as "an effective flip requires careful preparation"[15]. The CAD teacher would have to provide their own video based demonstrations and tutorials, which would be in some cases prohibitive if it was not for the provision of existing ready-made learning resources. There is also the student perspective to consider, who may not appreciate the value of the enhanced class activities against face-to-face lectures [15]. From the students surveyed, 52% of students believed flipping the 1 to 1 lectures with online video lectures would not make a difference to their learning outcome. 26% of students believed they required physical lectures in order to progress.

8 OPPORTUNITES

The technological nature and enhancement of CAD software presents some interesting opportunities. For example, the latest version of Siemens Solid Edge allows users to record and upload their CAD sessions onto Youtube. This presents an opportunity to the teacher as they can record CAD demonstrations or tutorials if Panopto is not accessible or unavailable. It also presents an opportunity for students to record their own CAD sessions, which can give instructors and teachers a deeper level of assessment and feedback. Teachers could potentially view students CAD work in real time, and make observations on how students constructed the model (and how long it took to construct sketches and features) rather than simply the order of features themselves (which can be viewed in an existing playback function). It also empowers students to share their CAD work among friends and online communities-and seek assistance and learning opportunities beyond the classroom (many CAD vendor sites have community and user forums). Many CAD applications now integrate with tablet and mobile devices, with express views of CAD models, assemblies and explosions. This has the potential to further enhance access to educational resources via mobile devices.

9 THREATS

The provision, content and control of these learning resources are externally controlled by corporations, not academic institutions. One threat is the idea of certification, in that students receive recognized credentials of using a particular 'brand' of CAD software. Currently, Autodesk and Solidworks promote this as a way of enhancing CV's and placement applications, however, it creates some blurred lines between what one would perceive as 'training' and that of 'teaching'. Another threat is authorization, where only authorized teachers can teach particular CAD packages. For example, with Rhino surface modelling, this is only required for corporate-level training purposes (teacher workshops are free). With changing market conditions in higher education, exploitation needs to be discouraged. Ultimately, the learning resources are under the CAD vendors control, and there can always be a conflict of interest between what a corporation wants to 'teach' and what students actually need to 'learn'. Universities are often tied in to particular packages, which can make situations awkward if access and restrictions to learning resources change. For example, CAST (Computer Aided Self Teaching) was an add-on for Siemens NX which allowed access to web-based tutorials. This has now been replaced with Learning Advantage (NX9 onwards) [16], which provide similar self-paced tutorials but as a separate membership based account. This now comes at an additional cost (whereas CAST was provided free with the software). The problem with this membership based system is that it focuses on individual, corporate and enterprise memberships, not large cohorts of students and teachers in an academic context. After all, industries are a CAD vendor's core customer base. This change in provision adds complication to e-learning provision and teaching material in future upgrades.

10 CONCLUSIONS

Teaching efficiency and enhancement, as well as changing market conditions, are driving changes towards flipped teaching methods. Video-based learning technologies and self-paced e-learning materials are enabling this change. In the context of CAD teaching many of these technologies are readily available from vendors and can save vital teacher preparation time. Students seem supportive of the idea of doing CAD tutorials in their own time, as well as having an online video version of the class introduction. The merits of a hybrid flipped teaching method heavily outweigh a fully online CAD course, but careful management needs to be taken to ensure students get the appropriate support in the physical class session to complete outstanding activities. The integration of CAD with video, online communities and mobile devices offer interesting opportunities for learning enhancement.

However, with many CAD orientated e-learning resources outside teachers control and influence; the business of 'teaching' opposed to 'training' needs to be upheld. These points are summarised in the SWOT analysis in Figure 3.

	Helpful	Harmful
Internal	*-More time /content coverage for student learning* *-Self paced learning* STRENGTHS	*-Managing activity progress/completion* *-Value perception* *-Preparation* WEAKNESSES
External	*-Deeper assessment & feedback* *-Flexibility of digital content* *-Peer learning* OPPORTUNITIES	*-Some content out of academic control* *-Cost or access restrictions* *-Train vs Teach* THREATS

Figure 3. SWOT analysis of key conclusions

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TEACHING ENGINEERING DRAWING IN A TECHNOLOGY CHANGING ENVIRONMENT

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ABSTRACT
Engineering drawing is one of the oldest technologies used in mechanical engineering and therefore also one of the oldest subjects of engineering study courses. Since the last century, engineering drawing has moved on from a subjective way of drawing to a very formalized common language among engineers. In addition, the drawing technology has changed from paper based 2D drawing to 3D volume modelling with help of computer aided drawing (CAD) systems. The 2D drawing is now only one point of view onto the product describing information. Parallel to the drawing technologies, also the teaching technologies have developed over the last decades. Especially during the last decade, the Institute of Mechanical Engineering introduced different teaching methods into it’s engineering drawing course. This paper analyses the consequences of those changes for the learning success of the students over the last 8 years.

Keywords: Engineering drawing, e-learning, CAD, videos, multimedia.

1 INTRODUCTION
Engineering drawing is one of the oldest technologies used in mechanical engineering and therefore also one of the oldest taught subjects at universities in mechanical engineering. During the last 30 years the drawing education has rapidly evolved. Trends started with 2D CAD over 3D CAD to manufacturing without drawings must be integrated into the lectures. Additionally, also the learning environment is changing from first e-learning modules on to smartphone and video based learning.

2 EVOLUTION OF ENGINEERING DRAWING AND THE USED TECHNOLOGY

2.1 Changes in engineering drawing and used technology
The basic methods of engineering drawing were discovered at the ancient world and evolved slowly until the end of the mid ages. Then, the reintroduction of the central projection in 1420 as well as A. Dürer's textbook, describing the usage of the plan and elevation method in 1525, pushed the engineering drawing forwards. At the beginning of the 19th century, patent drawings continuously gained in importance. Starting with the standardization activities in the early 20th century, engineering drawing developed further and became a formalised engineer’s language, understandable worldwide (compare [1] and [2]). Beginning in the 1960s computer programs were introduced to support the engineer creating 2D drawings and started the era of computer aided design (CAD). At first they only support 2D drawings and therefore replaced the drawing on paper, without introducing a new basic drawing technology. In contrast the new 3D CAD Systems, introduced in the 1980s, changed the complete engineering drawing process completely. From then on, not the 2D representation of the product was focused, but a complete 3D volume model. The 2D engineering drawing is only one view on that model. All needed information should be stored within the 3D model. Nevertheless, the engineering drawing remains important as a legal document and part of the contract between the supplier and the customer. Also the fast creation of 2D sketches during discussions, in order to communicate ideas or as part of the thinking process is common usage of basic engineering drawing skills.

2.2 Changing educational technologies

Following [3] the history of machine supported learning started at the end of the 19th century with the spelling machine from H. Skinner in 1866. The machine displays a picture and the user should enter the correct word, shown on the picture. Later on, at the first decade of the 20th century, educational films extended the media supported learning methods [4]. At that time, H. Aiken patented an improved spelling machine, very similar to the one from H. Skinner. Aikens machine was based on the law of effect theory by Thorndike. Thorndike found out that an association is strengthened if it is followed by a reward. In the following year many learning machines, utilizing this theory, were invented. This included the mechanical teaching machine from S. Pressey in the 1920s. Also the first test, containing only multiple choice questions was introduced during the world war I to test US military recruits. In 1938 a first machine supporting a linear learning program, based on operant conditioning, was invented by B. F. Skinner and J. G. Holland in the US. Those programs presented the content in small pieces followed by questions in order to test the understanding. In 1959 N. Crowder introduced the branching program which allowed individual sequence of the content presentation. One year later the University of Illinois started a classroom system with linked computer terminals where the students could access additional learning resources while listening to the recorded lectures. In 1971 the National Science Foundation (NSF) started the research projects TICCIT (time-shared, interactive, computer-controlled information television) and PLATO (programmed logic for automatic teaching operation) to prove the efficiency and cost effectiveness of computer based learning methods. From the NSF point of view, both projects were successful and proved the advantages of e-learning methods. Since the 1990s e-learning has become more important as well as widely used, caused by the rise of the internet. Today the new smartphones and tablets are changing the e-learning environment again, moving the learning activities from the pc to mobile applications.

3 THE ENGINEERING DRAWING COURSE

In 2005 the students learned the theoretical basis in a lecture, supported by the lecture notes. Those lectures were recorded and the students could use the recordings to prepare for the practical exercises (s. [5]). As ***Table 1*** shows, the students must pass 7 exercises in 2005. They started drawing a free hand sketch of a simple part using parallel projection and anometric view. The drawn part was provided as a physical model. Within the exercise A2 the source was an axonometric view of another machine part. The students created an engineering drawing in parallel projection from the axonometric view and also added dimensions according to the German drawing standards. The third exercise treated the correct drawing of machine elements like nuts and bolts. Based on provided assembly drawings the students had to add the nuts and bolts to the drawing. The task A4 dealt with welds and the related symbols on technical drawings, A5 covered calculations of tolerances and fits. In frame of the task A6 the students changed a given assembly drawing and added 5 different machine elements to it. During the last exercise the students created an engineering drawing of a given physical part. They had to determine the dimensions and all needed information to create a part drawing suitable for production. In addition to the drawing tasks the students had to pass two multiple choice tests, asking questions about drawing rules. Since winter semester 2005 the students attended 15 training hours in parallel in which they were introduced in the usage of the CAD system Pro/ENGINEER (now called Creo Parametric). Before the 2D CAD system Medusa was used. The CAD part ended a small practical test in which the students had to model a simple part. The course has been passed if every exercise and the three tests (Test 1, Test 2 and CAD Test) has been passed.

Based on the e-learning module pronorm, introduced in 2007/08, the lecture notes has been renewed. Nowadays they contain a compressed version of the e-learning content. Thereby the students could lookup content while practicing engineering drawing. The deeper theoretical studies should be done with help of the e-learning system.

In 2010 the complete structure of the engineering drawing part has been redesigned. The lecture has been shortened up to the introduction and the organisational part. Also the drawing exercises have been changed. The tasks A3 and A4 are combined and shortened up to A3. A6 has been removed and A7 replaced A4. Additionally, A5 was replaced by a CAD task, where the students should build and draw a small assembly with help of the 3D CAD system. The drawing should also contain fits and tolerances as a precondition to achieve the desired functionalities. As a result, the CAD part and the drawing part have the equal time slice.

Until 2013 some more changes have been made. The CAD lecture notes are now available as a website and in a printed version. The website is the homepage of the internal browser within the CAD system. So students in higher semesters can access the lecture notes without leaving the software. This is very welcomed by the students because they are using the CAD system in a productive way in the higher semesters to complete their thesis or other work. On the drawing side the e-learning environment has neither been used very often nor intense by the students within the course or afterwards. Therefore the institute decided to stop offering the e-learning module for the students and use it as a content source for the lecture notes only. As a replacement a small video for every drawing task (s. [6]) has been created. The videos introduce the topic in a practical way, discussing some very common problems related to the task and showing a best practice approach.

Table 1. Exercises in engineering drawing in 2005 and 2010

Exercise	*2005* Content	Attendance time	*2010* Content	Attendance time
Lecture	-	2,0h	-	0,5h
A1	- Free hand sketch of a simple part (physical model) - Parallel projection - Axonometric view	2,5h	- Free hand sketch of a simple part (physical model) - Parallel projection - Axonometric view	2,5h
A2	- Sketch of a part (axonometric projection) - Parallel projection - Dimensions	5,0h	- Sketch of a part (axonometric projection) - Parallel projection Dimensions	5,0h
A3	- Draw Nuts and Bolts in assemblies	5,0h	- Draw Nuts and Bolts in assemblies - Draw welds and weld symbols	7,5h
A4	- Draw welds and weld symbols	2,5h	- Drawing of a physical part - Suitable for production - Fits and tolerances	5,0h
A5	- Calculate Fits and tolerances	2,5h	- Creating and draw assemblies with CAD	7,5h
A6	- Changing a given assembly drawing - Add 5 machine elements	7,5h	-	-
A7	- Drawing of a physical part - Suitable for production - Fits and tolerances	5,0h	-	-
Test 1	Multiple choice	-	Multiple choice	-
Test 2	Multiple choice	-	Multiple choice	-
CAD		5 x 3h = 15,0h		5 x 3h = 15,0h
Σ Drawing		30,0h		20,0h
Σ CAD		15,0h		22,5h
Σ Total		47,0h		43,0h
Percentage Drawing		64%		47%
Percentage CAD		32%		52%

4 EVALUATION OF THE LEARNING METHODS

One evaluation source is the result database of the students in engineering drawing hosted at the institute. ***Figure 1*** shows the student's results per exercise over a time range of several semesters. The reached points of Test 1 (T1) and Test 2 (T2) are much lower than the ones for A1 – A5 because the tests have 15 points at maximum und A1 – A5 100. It can be seen, that the results are very constant over the years. The results of nearly all exercises and tests are located inside 2/3 to 3/4 of the maximum points. At first view this result is a bit unfruitful, but closer inspecting it reveals possible root causes for this behaviour. One reason is the data basis of the statistics. The values represent all currently last tries of the students, whether successful or not. Since the course could be repeated as often as wanted by the students, some students participated one time and other 2 times or even more often. Some students paused between the attendances for several semesters. Therefore an assumption is, that the repeating ratio will lower in future. Nonetheless, this is not yet measurable due to the above described facts.

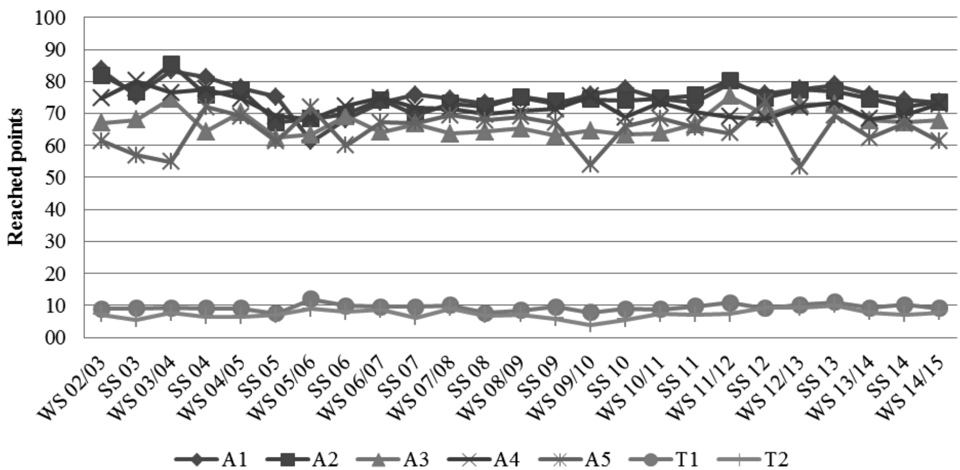
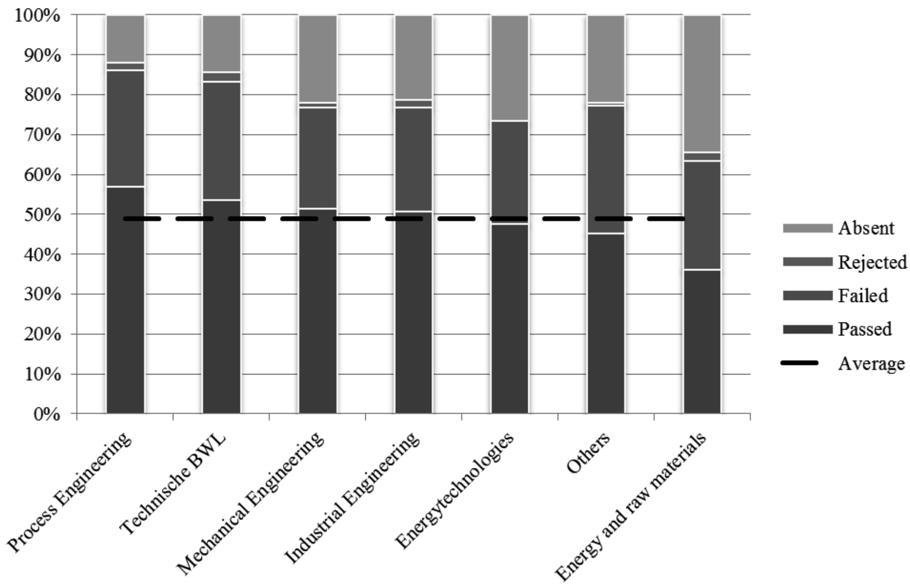


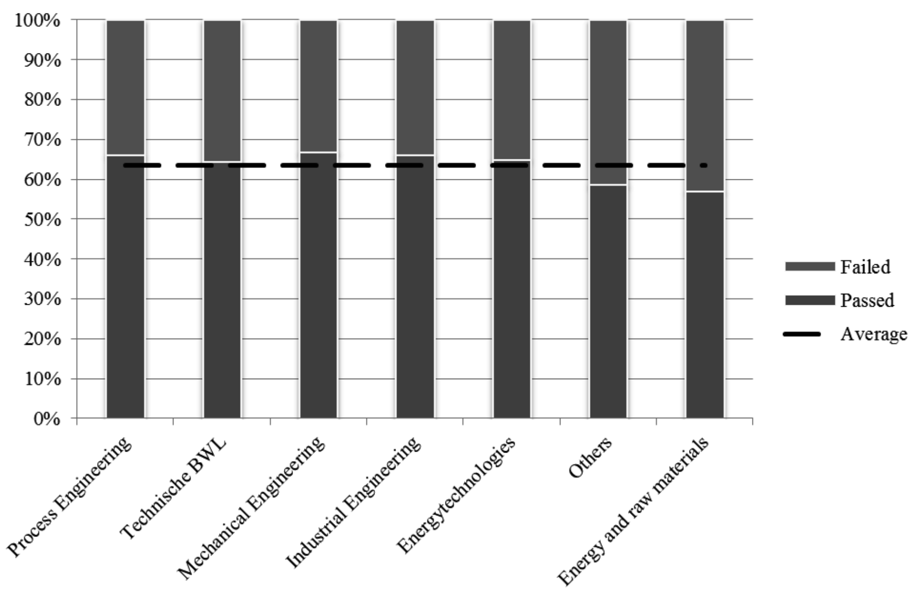
Figure 1. Average result per returned exercise and semester. On exercise A1 - A5 the maximum is 100 points, whereas T1 and T2 has 15 points as maximum

Another reason for the shown constant results might be caused by the fact that engineering drawing belongs to the basic study courses. The students must learn some rules about the drawing language's rules. Furthermore they have to train their geometrical imagination. There is no complex mathematical or physical background. Therefore the motivation and not the abilities of the student is the most important factor. ***Figure 2*** encourages this relation. In ***Figure 2***a there is a difference of about 20% (standard deviation 7%) between the study course with highest percentage of passed students and the lowest one. Excluding the students which were absent within the test or did not attend the exercises for at least 3 times (rejected), the difference between maximum and minimum passed ratio is only about 10% (standard deviation 4%). This indicates that not the study background of the student is important, but only the motivation to attend and finish the course.

Based on the described statistical findings, other criteria must be used to evaluate the realized activities. A first source for an additional evaluation of the used methods, are the standard evaluation sheets and the direct feedbacks of the students. With the help of those sources, the online lecture notes for the CAD part and the videos for the drawing part are highlighted by the students. Another source are visitor statistics of the offerings. For example ***Figure 3*** shows the rising usage of the teaching videos of the drawing course. In the first semester of this offering, only every 4^{th} student has watched the video before starting to work on the exercise. In the last semester, each student watched the video 1.25 times in advance. So, these videos are one of the main preparation sources. On the other hand the visitor statistic of the e-learning module clearly shows that almost no student used it. This might be caused by two reasons. The first reason could be related to the lecture notes themselves. They provide enough information to prepare for the exercise and successful finish them. On the other hand, using smartphones and tablets for browsing the internet, is very common. But the e-learning module was designed for larger displays and is not usable comfortably on smartphones or tablets. The integrated monitors in the drawing tables were also not competitive enough with smartphones. So the students used the internet on the smartphones to lookup something more often than the e-learning offering.



a) Including absent and rejected students



b) Excluding absent and rejected students

Figure 2. Percentages of results for the students including absent and rejected (a) and excluding absent and rejected (b) students

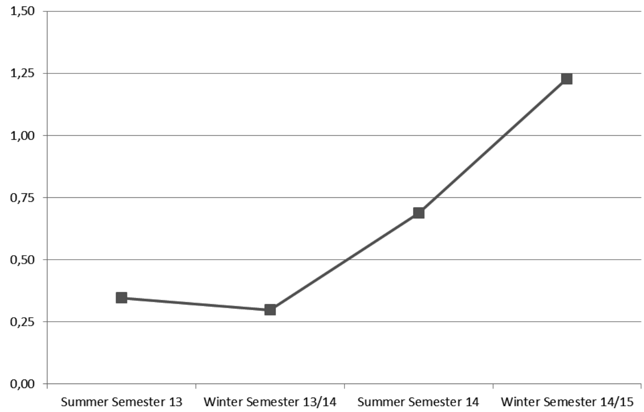


Figure 3. Average count of video views per student

5 SUMMARY AND CONCLUSIONS

The engineering drawing course at the Institute of Mechanical Engineering has been in constant flux until today and will also be in the times to come. Since 2005 the share of the CAD part raised from 32% to 50% of the attendance time. In parallel the used learning methods have changed. Starting with recorded lecture notes in 2005 and e-learning offers in 2007, the recorded lecture notes have been used by the students to prepare for the exercise, whereas the e-learning module has not been accepted by the students as expected. As one reason for this the upcoming smartphone and tablet era has been identified. The e-learning module has not been ready for that. Therefore, the e-learning offer has ended in 2013 and been replaced by small introduction videos for each exercise in the drawing part.

Evaluating the acceptance and success of the changed learning environment, it has come out that the new methods have not yet raised the reached points in average. Nonetheless other statistical results have shown that there might be a stronger correlation between the student's motivation and finishing the course successfully than between the knowledge background of the students, due to different study courses. Since the students find the videos very useful and the hit rates are rising, as shown in ***Figure 3***, the videos may stimulate the student's motivation. A rising motivation should be followed by sinking repeating rates per student, which could not be analyzed yet. To analyze repeating rates, a longer history after the introduced changes is needed. Therefore it will be a possible metering in the future.

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UNDERSTANDING AND CREATING 3D FORMS USING FAMILIAR OBJECTS

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ABSTRACT
A fundamental for first-year design students is to express ideas by drawing and creating volumetric models. Traditionally, this education includes spatial geometry and generation of forms whereby students learn to appreciate intersections of volumes and projections to describe three-dimensional (3D) forms in two dimensions. However, given the aptitude of today's students to operate 3D-modelling software and the general accessibility of current technology, spatial geometry as a core subject may seem less relevant. Our goal is to re-engage students in learning required basic knowledge and skills through a complex multifaceted design process. We have designed a first-semester course of four project-based learning activities that apply learning-by-doing methodology. For each of the past three years, 65 to 75 students have participated in our 3D Expression studio course, in which they develop understanding of design process, vocabulary, and skills to create 3D models with precision, refinements, and high-level visual impact. This paper reports on the successful results of activities conducted during the 14 full days of this studio course.

Keywords: Design education, learning-by-doing, design methods, spatial geometry, 3D construction.

1 INTRODUCTION

A cornerstone in design education is "basic design"—defined by many schools in reference to Bauhaus and, particularly, works of Kandinsky. Teaching centres on distinguishing basic elements from other elements, "elements without which a work cannot even come into existence" as mentioned by Lupton [1]. Understanding and mastering 2D drawings, 3D forms (volumes, interaction of shapes, etc.), composition, colour, and materials and familiarity with techniques are considered fundamental to all design expression. This understanding is reinforced in studio course activities, whereby students expand their comprehension by making connections with their learning. Traditionally, basic design includes spatial geometry and generation of 3D forms. But given the aptitude of today's students to operate 3D-modelling software and the general accessibility of current technology (e.g., 3D scanning, generating surfaces in complex modelling), teaching spatial geometry as a core subject may seem less relevant. Therefore, we have established a teaching approach to design focused on understanding and creating 3D forms along with development of visual vocabulary. The teaching is studio-based and offered to first-year university design students, who come from a variety of high-school backgrounds; many have never studied in art and lack skills in drawing and handcrafts. The course is mandatory and taken immediately following an introductory course on basic 2D drawing, where students learn about observational drawings and perspective.

The course is called 3D Expression. Pedagogy is student-centred and applies the backward design model [2]. The theoretical project-based framework targets development of creativity and innovation based on constructivism ideas of Dewey [3] and Piaget [4]. As Piaget explains, [4], "Knowledge is actively constructed by the learner, not passively received from the environment." Project-based, experiential, and hands-on learning has always been a tradition in design education.

The learning curriculum consists of a set of "projects" (see Section 3). The projects are introduced in sequence to help students develop competencies in imagining harmonious 3D forms and expand skills in creating models. Understanding and applying notions of point, line, coordinate systems, axes, planes, projections, transformation, intersection, rotation, etc. are embedded in the exercises.

This curriculum has been applied since 2012, involving 65 to 75 students each year. Teaching is supported by cycles of individual coaching and feedback to help students acquire understanding of the process leading to creation of innovative 3D forms—enriched by visual design vocabulary. Students also develop skills to create precise 3D mock-ups with simple materials and low-tech applications.

2 EXPERIENCE AND LEARNING

With the goal to construct knowledge on principles of generation of 3D forms, first-year students are placed in an experimental set-up where they are asked to draw on past experiences, understand a current situation, and then create new 3D artefacts. Dewey's leading ideas of experience and learning-by-doing [3] are central: Students receive limited instructions and undergo an iterative process to build knowledge. The pragmatic aspect of experimentation is essential for designing and developing new artefacts "to foster skill development and the learning of factual information in the context of how it will be used" [5]. Dewey's project-based learning [3] is arguably the most significant contribution to design education. Among the benefits of this student-centred strategy are greater understanding of concepts within context, heightened creativity, improvement in communications, and better response to feedback. Project-based learning is considered to be a comprehensive approach that engages and motivates the learner [6]. Another key advantage of project-based learning is that students integrate knowledge and skills through a process of learning-by-doing. Learning-by-doing is significant because students develop a sense of critique and reflexive practice toward their actions and experiences [7], [8]. They engage with the learning experience to become more independent and develop critical thinking. Furthermore, project-based learning encourages active involvement of students in sharing knowledge through collaborative discussion and problem-solving [9]. Other important components of learning-by-doing are the physical conditions where learning occurs (environment and tools) and the coaching of students [6].

2.1 Backward design process

Explained by Wiggins & McTighe [2], backward design aims to provide learning experiences for better understanding of subjects and processes by setting goals before choosing instruction methods. The model has three basic stages: (1) identify desired results; (2) determine acceptable levels of evidence that results have occurred; and (3) plan activities that enable results to happen. In project-based teaching, it seems important to add an additional stage to the model: "coach" the process.

2.1.1 Stage 1: Desired results

First-year students start basic design education with a concentration on observation drawings (2D expression), where they explore use of media, composition, light, and shades. This is followed by 3D expression. Each of these studio-based trainings is conducted two days a week for seven weeks. The belief is that observational understanding is key to make sense of formal, perceptual, symbolic, and technical aspects of objects. Thus, the following goals were defined as desired learning outcomes:

- Discover, analyze, and identify the visual language and patterns of an existing object through specific terminology. Interpret and apply the visual language to another object.
- Communicate intentions through drawing and 3D models with different materials.
- Put learned principles into practice in design projects.
- Develop understanding about the design process: learn to accept that new and more interesting ideas can be developed through iterative exploration.

Exploration activities in the studio allow students to develop the ability to imagine, design, and modify volumes in space. Students also experiment with creative problem-solving, which they will apply later in designing products. They work with simple mediums: mostly pencil for drawing: a variety of papers and metal wires for creating 3D shapes. They learn precision in craft techniques, composition, and visual vocabulary: harmony, contrast, balance, etc. This first introduction to project-based learning at university focuses on the design process as a hands-on experimental and iterative activity, and is based on the following theoretical concepts: spatial geometry in design; methods of representing 3D forms in 2D and vice versa; decomposition, intersection, addition, subtraction, and repetition of forms.

2.1.2 Stage 2: Knowledge transfer and evidence of results

Students work on exercises and projects in the studio individually, except for the last project. A tutor who is a professional practitioner is assigned to every 12 to 15 students. The studio facilitates transfer of theoretical knowledge by allowing students to apply their learning in projects. Theoretical content is provided in the form of short lectures, conferences, and demonstrations; tutors also share case studies from their practice. All studio work requires multiple iterations during development and representation in 2D and 3D. For each exercise or project, the acceptable level of evidence that results have occurred is defined and discussed with tutors, who closely follow the development of students and help them to overcome challenges. Three levels of assessment are acceptable: Level I (lowest) is application of learned theory to a project. Level II calls for in-depth understanding of issues when theory is applied to a project. Level III includes criteria of the other levels plus familiarity with design vocabulary.

2.1.3 Stage 3: Activities

Students undertake six exercises and four projects. The exercises are preparation for the projects. Each project begins with analysis of a familiar concept or artefact and leads to creation of a new abstract 3D form. At the beginning of each project, students receive a document that outlines process, timeline, desired learning results, and evaluation criteria. Students are asked to use oversized paper for sketches and advanced drawings and to assemble them for future study of their progress.

3 PROJECTS, SEQUENCE, DEVELOPMENT

3D Expression starts with a short team-building activity. A set of exercises and projects are introduced in a set order to build student knowledge and skills. Learning from each exercise has important consequences on following projects and each project has an impact on the succeeding one. In other words, projects are building blocks to desired results. The first two projects are presented below; they have proved to be effective approaches for knowledge transmission and learning.

3.1 Understanding 3D through carving: a subtractive process

The first experimental project is a ludic introduction to 3D forms. It challenges students to create a letter of the alphabet in 3D. The main steps of are the following: (1) Students select three letters of their names and imagine the letters in 3D. They explore making models of their imagined 3D letters by removing material from a mass—carving a potato. (2) Students display their "artworks" on a large table for observation and comment. Five potato letters are selected that have the most interesting 3D constructions and best proportions from all angles. These five letters serve as models for the next step. Figure 1 shows a grouping of potato letters prior to selection of the most promising ones.

Figure 1. 3D letters created by carving process

(3) In this step, the goal is to create a 3D letter in cardboard inspired by one of the five potato models. Students sketch and refine the shape of the 3D letter, make precise technical drawings, and think about strategies of construction of the letter in cardboard. The required height of the letter is 30 cms; students define the other dimensions. The conceptual model that is the result of this activity is an individual and subjective interpretation of the selected letter.

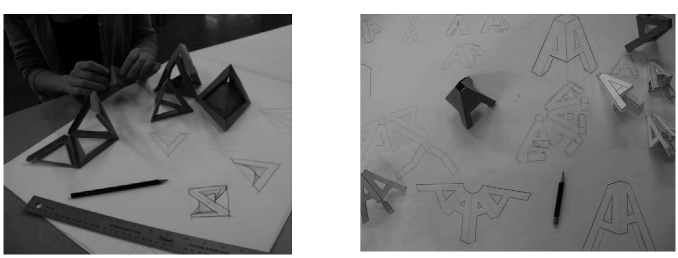

Figure 2. Process of drawing and construction of model

The activity allows for comment on the following capacities of students: to select a letter that has an interesting complexity and structure; to generate a 3D form based on a familiar 2D form; and to carve (subtract) a form from a solid based on a cognitive model. The unusual material (potato) creates special motivation and excitement. With this simple and playful exercise, students by the second day of the studio are developing sharing and interaction skills, critical thinking, and visual understanding. Resnick and Rosenbaum [9] qualify this kind of approach as "tinkering," which is "characterized by a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities." The project workshop takes two days of the 3D Expression studio. Figure 2 shows the drawing process, developing layout strategies for construction, and testing interaction of folded cardboard volumes. Figure 3 shows selected end results.

Figure 3. Examples of 3D letters

3.2 Understanding special geometry of 3D forms

The second project helps students to acquire understanding of 3D objects and create new ones that share similar principles. The activity is based on: (1) study of spatial geometry of a familiar object by observation and analysis to find its visual vocabularies; (2) creation of a new object by considering the visual vocabularies as principle guidelines. This project takes four days over two weeks.

The method consists of the followings three steps. (1) Students choose a bottle from among three types that seem to be *a priori* common: a shampoo bottle with an organic shape; a soft drink bottle with a rounded shape, comparable to a female body; or a mouthwash bottle with sharp edges, representing robustness. They observe the bottle carefully, measure and draw it, and study its shape by noticing axes (i.e, symmetrical, rotational), by breaking down its volume into simple geometrical shapes (i.e., parts are parallelepipeds, cylinders, cones), and by identifying interaction of volumes (i.e., addition, subtraction, merge, union). This step allows students to distinguish proportions and formal structure that makes the bottle to be in balance, stand-alone, etc. Thus, students identify the formal vocabularies revealed by the object. (2) Based on understanding of forms and visual vocabulary of the bottle, students draw variations and make mock-ups of volumes. Three proposals are selected to be further developed by drawing orthogonal and perspective views. (3) The most promising proposal is then selected as a starting point to build a model of a new object. The goal of this step is to build an abstract form inspired by the visual vocabulary of the original bottle three times larger than its actual size. The rescaling detaches the form from its original function and helps students to study the basic elements of the new form. It also adds new challenges related to proportion, visual harmony and structural balance, technical drawing of the new form, and strategies of construction of mock-up. Through discussions with their tutor and trial-and-error, students develop a strategy for building the form with cardboard. Several test models are needed to validate the method of construction of the final model. Students are encouraged to anticipate creases and common edges between shapes and to minimize breakdowns and chunking shapes.

Figure 4 shows examples of early drawings by a student that helped to understand geometry and interaction of forms, proportions, formal and structural guiding lines, rhythm, and vocabulary of forms. The image on the right illustrates the abstract artefact—60 cm in height—created as a result of the project. The foundations and impacts of this project are discussed in detail in another paper:

“De(re)construction of Geometrical Forms.” This approach reveals to students the iterative process of design. The approach also makes students realize that good planning and rigorous execution allows for considerable time-savings when creating cardboard models.

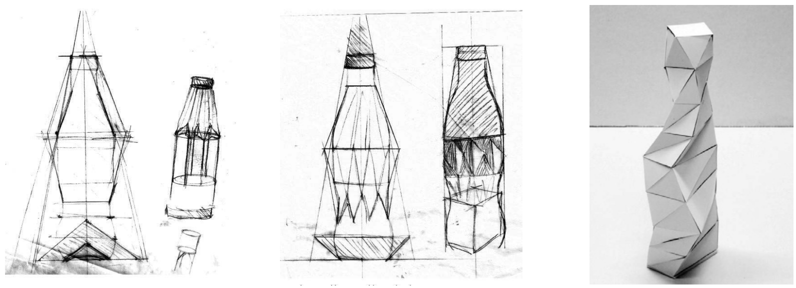

Figure 4. Example of transformation of original object into abstract form

3.3 Next two projects

The third and the fourth projects (not part of this report) reinforce learned concepts and challenge students with greater complexity and more precise constructions: an individual project on better understanding of visual design vocabulary; a collaborative project by teams of two on design of a 3D construction inspired by the human body.

4 RESEACH METHODOLOGY

The first author of this paper taught a theoretical course on spatial geometry for design students prior to transforming the teaching into project- and experimental-based studio content. She redesigned the pedagogical method of this particular spatial geometry course (now 3D Expression) and conducted the studio course for three consecutive years. The second author played the role of coach. He worked very closely with a number of students, encouraging them to explore, test ideas, and learn from mistakes. Both authors together observed students’ progress as well as difficulties in understanding concepts and in developing skills in representing 3D ideas with different materials and techniques. Exercises were adjusted and new ones were added to create better transitions between projects. Theoretical modules, expert demonstrations, and specific guidelines were also added and provided for students to enrich learning methods. This teaching/adjusting approach follows on Kolb’s four-stage cycle of experiential learning: concrete experiencing, reflecting on observations, generalizing, and applying (new experience) [8]. The cycle allows for exploration of processes associated with making sense of concrete experiences.

5 DISCUSSION

Our students are from diverse education backgrounds, and thus they have diverse ways of thinking, learning, and overall functioning. In their learning, they have the challenge of understanding “design thinking” and acceptance of “ill-defined” problems [10], [7], which can be difficult and destabilizing. We also expect students to explore and understand the iterative process of design [11].

As design educators, our challenge in teaching spatial geometry was how to help students to develop a hands-on understanding about interaction of 3D forms without using software applications—how to help them develop skills in generating new forms. With the first project, we found that students’ experiences of carving helped them to visualize and understand interaction of simple geometrical volumes. Then, the carved model was used in interpretation of the 3D concept in 2D drawings, refinement of the concept, and study of proportions; precise drawings led to construction of 3D letters. While students showed little difficulty in meeting project requirements, results related to quality of performance, precision, and cleanliness of models were mixed.

The second project imposed a greater requirement to follow constraints, beginning directly with 3D observations of a specific bottle. The question became: How can novice design students be taught to carefully “look” at 3D forms of familiar objects, analyze them, and grasp their visual characteristics to apply to the creation of new objects? Through reinterpretation of a bottle and many iterations of its form, students were guided to develop ability to express creativity. By rescaling the size, students became detached from the original form of the bottle and its function. Figure 5 illustrates student evaluations through two workshops, and reflects their progression from an average grade of C+ to B.

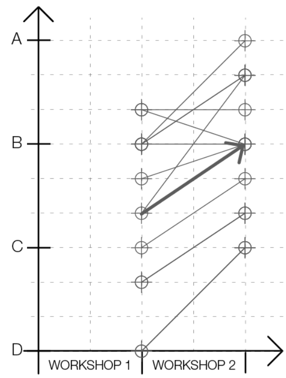

Figure 5. Student evaluations through two workshops

6 CONCLUSION

The teachings of 3D Expression, which includes principles of geometry, can be considered as part of a liberal arts education that helps students to develop creativity and a sense of aesthetics. In Plato's words, geometrical forms are "forms of beauty". In art and architecture, geometry is traditionally a foundation subject in most design curriculum; however, while it remains a subject that contributes greatly to design, its teaching by traditional methods and tools may have lost connection to other subjects of design studies. This reflective report enabled us to validate that students are able to express new mental constructs and develop a deep sensitivity to forms that is useful in designing products. The results of proposed methods and the feedback from peers and students confirm the belief that the projects of the studio course help students to improve understanding of volumes, capacity for imagining new abstract forms, critical thinking, understanding of the iterative process of design, understanding of visual vocabulary, and development of skills in the creation of models based on deeper understanding of underlying geometry.

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Chapter 5

Pedagogy

GENERATIVE PROTOTYPE ITERATION IN THE FRONT END OF THE DESIGN PROCESS

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ABSTRACT
Iterative prototyping has traditionally enabled engineers and designers to test concepts in the latter stages of development once problem and solution have been defined. Exploring the use of this technique in the problem definition area of research to stimulate interaction and discovery during co-design [1] has the potential to generate insightful, user driven ideation.
Combining and taking inspiration from Presumptive Design [2], Speculative Design [3] and Co-Design through making [4], this research introduces a fruitful connection between provocative artifact engagement and user generated ideation, while implementing digitally fabricated objects, in the generative front end of the design process.
A six-person multi-disciplinary design group generated an initial, 'Presumptive' artifact followed by subsequent user inspired objects. Four workshop sessions involving a total of thirteen different participants were facilitated during three iterations. Workshop participants were introduced to ill-conceived artifacts and asked to critique and reflect. The artifacts were not introduced as valid prototypes, only objects to spark conversation about the cycling experience at The Ohio State University. Through discussions, observations and the use of maketools [5], participants documented their responses and needs for future use. These responses were then used to inspire and provoke the design group to further evolve the discussion and iterations while exploring the problem space. The digitally fabricated, provocative artifacts created by the researcher stimulated users to discuss and ideate in a co-creative setting, eventually leading to a clearer understanding of their future needs. Interaction with artifacts and designerly concerns introduced participants to product evaluation and critique that was then applied to their own considerations. The process transformed the sacrificial artifact, through a series of iterations, into a physical representation of a solution to those needs.

Keywords: Co-design, prototyping, generative, provocative, iterative.

1 BACKGROUND: RESEARCH THROUGH MAKING

Throughout this paper, reference to 'artifacts' can be interpreted as "objects whose function is not to test or prove, but which provoke reflection, experimentation and discussion." [6] This interpretation considers tangible objects as a means to explore ideas and concerns, not to assess physical attributes or perceived use.
When applied to problem space exploration, participatory design research can be used to facilitate co-design workshops with future users in order to discover insights and new opportunities. Incorporating methods that engage participants and spark meaningful conversations to create insight can be challenging, however. Even more challenging is getting people to express their tacit and latent knowledge and use it in designerly ways of thinking and making [7].
Over the past 20 years design research has expanded to include designers and engineers searching for inspiration and insight. The introduction of those skill sets means more 'designed' materials and objects entering the field of qualitative research. "This new generation has been trained in design, making them not only keen to undertake research with holistic qualities and to seek out knowledge which is highly relevant for application by design(ers), but also to apply the methods and techniques from design to use in a research project." [8]
This investigation has been inspired and informed by design research practices from industry and academia. These practices are Presumptive Design, Co-design and Speculative Design.
Presumptive Design provided the inspirational foundation to explore ill-conceived artifacts through iteration. "The designer, with minimum input about the requirements for the project, creates a set of

solutions, puts them in front of the target user, collects data about the fitness of the designs, and then performs analysis that feeds into an iterative cycle.” [9] Participatory design research through making in the “fuzzy front-end” [10] allows multidisciplinary groups to engage with various stakeholders in order to co-design for problem areas of concern. [11] Presenting artifacts in participatory workshop sessions facilitates and empowers co-designers to collaboratively engage and respond to these artifacts. Scaffolding this activity with generative maketools can allow designers and co-designers to lead artifact evolution and speculate on future use. “Maketools are essential for encouraging people to engage in associative, bisociative and creative thinking… and can support the jump to imagining the future.” [12] Making stuff to make sense of the future, [13] supported by interpreting objects as “matters of concern, not matters of fact.” [14]

2 PROJECT: IDEATE, CREATE, ITERATE

“Cyclist on Campus” was selected as the main focus of the project as it meant a large pool of participants could be tapped into. The six-person graduate design group was multi-disciplinary with industrial design, mechanical engineering, visual communication and business represented. The design group all agreed that cycling on campus was an area that needed to be addressed and had potential for innovative insights.

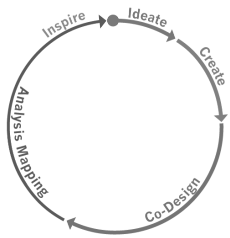

Figure 1. Proposed Generative Cycle: process repeated for each iteration

Understanding the needs of cyclists on campus and identifying areas of opportunity was the focus during the project. However, understanding the potential role of provocative artifacts in the front end of co-design was the overriding interest and research objective.

Tangible, low fidelity artefacts were introduced during co-design sessions to explore how their inclusion would influence participants to generate insightful responses related to their own cycling needs. (Figure 1) The four participant sessions investigated the means of artifact production and fidelity, participant response to ill-conceived objects, ideation through artifact interaction and discussion, and the application of iteration to co-design in the front end of design.

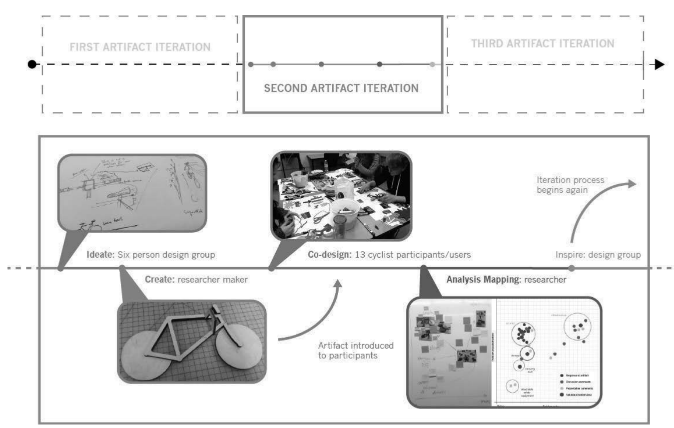

Figure 2. Iteration Timeline (Second iteration highlighted): As shown at the top of the figure, three iterations were done. The timeline at the bottom shows the second iteration only in more detail. Activities of the design group and the user groups are shown above the timeline and activities of the researcher are shown below the timeline.

2.1 Ideate and Create

The first design group session was a playful inquiry with multidisciplinary creatives ideating and speculating around the prompt “Cyclists on Campus”. The chosen bicycle rear-view mirror attachment, a combination of two concepts during ideation, allowed users to install their smartphone as a bike mirror, utilizing the front facing camera. (Figure 3)

Initially, the 3D-printed “Rear-view mirror smartphone attachment” was a crude, if usable prototype. The second and third iteration artifacts were only representative of the concept in a physical form that participants could interact with. The first artifact was quickly rejected as ‘trash’, so investing a lot of time to manufacture the object seemed unnecessary. For initial iterations the lowest resolution settings work best to provide an artifact that can elicit valuable response. Thinking of the artifact as ‘low resolution’ is a helpful way to understand the purpose of the object. “A prop can be a fully working prototype or not. This is not the issue; its purpose is to facilitate imagining”. [15]

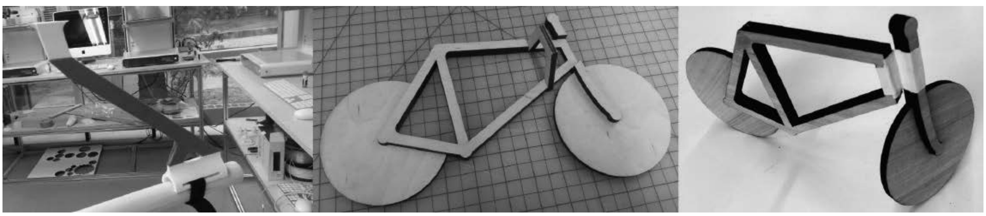

Figure 3. Artifact iteration evolution: The first iteration rear-view smartphone mirror attachment (left) was rejected during user co-design, the insight generated from the first iteration led the design group to incorporate a locking mechanism into the bicycle frame (centre). The final iteration was security themed but considered the use of ‘stigma’ instead of brute force to dissuade thieves (right)

2.2 First Artifact Iteration

Seven cyclists of varying abilities participated in two separate co-design workshops. In the hope of validating the process, both groups were provided with the same materials and were exposed to the same artifact. (Figure 5)

For the initial artifact, a CAD model was created, based on the sketches of the “rear-view” mirror concept. This model was then printed using a Makerbot Replicator 2.0. The cyclists shared their experiences of cycling in and around the city. Themes emerged during the discussions that were later mapped on the problem area abstraction grid. The cyclists were then introduced to the artifact and given a brief explanation of the concept behind it (Figure 3). Presentation of the artifact was carefully approached so as not to misrepresent the object as prototype. Participants had time to record their reaction to the artifact using a Deconstructive Map that exposed them to designerly considerations of concept, use, form and detail. They then placed the artifact on a scale from ‘Trash to Praise’ and explained their decision.

All participants responded negatively to the artifact citing a host of reasons that would later be analyzed to understand where the idea had failed, and what could be learnt for future iterations. Once every participant had contributed, they were asked to individually create a response to the discussion and artifact using the maketool materials provided. Participants were told this response could be related to the discussion and/or the artifact and could describe a problem or even provide a solution to that problem. The participants were finally asked to present their finished responses to the group.

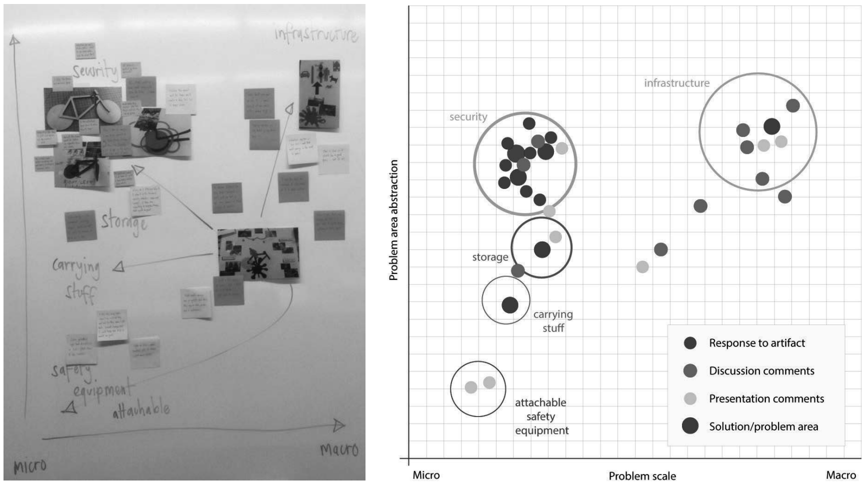

Figure 4. Problem Area Abstraction Map (Second Iteration): Documenting and charting what the participants created and discussed in relation to the artifacts helped to inform the design group's next iteration

The first and second cyclist workshop sessions discussed and produced responses that focused on security, wearable safety technology, infrastructure, bike trails, bike transportation, and attachable tech. When the data from both workshops was combined the two problem areas of "infrastructure" and "security" were of greatest concern. This newfound understanding of cyclists was presented to the design group through the Problem Area Abstraction Map (Figure 4) which acted as inspiration for the second round of artifact generation. Design group members took time to look at the images and read the comments before generating new concepts. The second artifact created was based on the perceived need for a bicycle lock that could be incorporated into the bike itself versus current independent locks.

Figure 5. Co-Design Workshops: All the sessions incorporated the same rules and materials to better gauge the success of each artifact, each workshop had different participants, 13 in total

2.3 Second Artifact Iteration

The third workshop involved three participant cyclists and utilized duplicate maketool materials to gauge the reaction to the new artifact. The second artifact merely represented the notion of a locking device that could be incorporated in the frame of the bicycle. (Figure 3) This artifact was much more 'successful' in the critique by the cyclists. It also generated a more focused and relevant discussion on a problem area.

Once again, the information gathered from the participant workshop was displayed on a fresh problem area abstraction map that allowed the design group to better understand the needs of the cyclists. The map also acted as a catalyst within the design group to raise questions about how to approach security. This meant consideration of storage versus security and how the two areas overlapped in the participant discussions and solution application. ‘Brute force vs. Stigma’ as a deterrent against bike theft was discussed in a quick sketch session. At this point, the design group better understood the nature of the iteration process and didn’t spend long imagining potential solutions and handing them off. The next concept speculated that by locking a wheel at a 90 degree angle, bike thieves would be less inclined to steal as the theft would be more suspicious. (Figure 3)

2.4 Third Artifact Iteration

The final artifact in this short series was taken directly from a response created in the second iteration workshop by a participant. This iteration tested the theory of ‘brute force versus stigma’ by presenting it to participant cyclists through the third artifact.

The three participants rejected the idea of stigma being used to protect their bicycle and focused on a system that would physically secure both the front wheel and frame by incorporating an inbuilt ‘cover’ that could be locked. If further iterations were continued; this would be the direction of the next artifact. The poor cycling infrastructure in the city continued to be an area of discussion, along with cyclist safety on the road. A new area that was highlighted was the need for seasonal bike access in the city. The cyclists complained about having to own something that was only used six months out of the year. A system whereby they could rent a bicycle during the spring and summer months appealed to both cyclists. Another suggestion was a bike that could be easily stored indoors for a six-month period.

3 ANALYSIS: ARTIFACT PROJECT

Understanding how the participants responded to each successive artifact was another way to gauge the success of the objects, beyond the problem areas highlighted. The visual below (Figure 6) represents the ‘direction’ participants expressed when creating a response to the first artifact iteration.

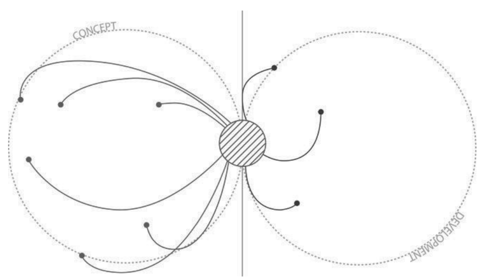

Figure 6. Artifact Projection: The responses could be divided into two areas: ‘Concept’ (left circle) and ‘Development’ (right circle). The center of the visual represents the artifact that the participants were provoked by. Each smaller point and line is a participant response created. The further the line was away from the center, the more abstracted or developed their response was.

The artifact allowed the participants to move either back into the conceptual (problem) area or forward into development (refinement). Overall, this visual helps to highlight the perceived success of the artifact on two differing levels. In the first iteration, more participants entered the Concept portion. This would suggest that they rejected the artifact in favor of their own perceived problems. If further iterations continued, the amount of participants entering this area would reduce as the design group moves closer to a need established by the previous responses. The third artifact could be deemed as a ‘failure’ in this analysis. However, the insight gained about the artifact would still be valid.

4 CONCLUSION

This method is still in development. Generative prototype iteration has potential to be used across the development stages of the design process, but will have the most impact during the problem space exploration and definition. The following establish considerations for using this proposed method:

Time, people, place and presentation are all important considerations. People: Research participants must be invested in the research topic in order to project their own inherent needs in response to an artifact. These participants can range from early adopters to laggards as insight can be gained from all when exploring areas of concern. The design team needs to also be fully informed that the process will strip away and reject ideas that are unrelated to the true user need. This means that members of the team should 'detach' from concepts that fail. Time: Early 'intervention' in the design process is critical to encourage new direction and development in the shortest amount of time. Place: The nature of the interactions and response process means that this method is best practiced co-presently. Presentation: The co-design process and presentation of the artifact is crucial. An artifact should not be introduced as prototype and participants should feel free to express ideas completely unrelated to the conversation sparked by the object.

In conclusion, low-fidelity artifacts can provoke participants to imagine and ideate on future use. How the artifact is interpreted is more important than its fidelity with 'low resolution' objects allowing for greater interpretation. The first object was the most 'product-like' and generated the greatest negative response, and wide-ranging concerns were expressed. The second artifact could be considered the most 'successful' as it was well received and generated a lively, focused discussion and ideation session. The third artifact was, again, rejected but confirmed insight from the previous sessions. The success of the artifacts is not determined by the initial response to the object, but by the information and insight gathered. From this perspective, all the artifacts contributed to inform the design process.

To further this investigation, a comparative study of artifact inclusion vs. exclusion in co-design workshops would establish how the introduction of artifacts affects the outcome. Analysis of different materials and processes of making could also be further explored to determine a relationship between insight and object fidelity. This research focused on the design team and end-users for insight and inspiration, however, involving stakeholders such as engineers, non-users (pedestrians) and producers could generate a more holistic understanding and potential solutions. Finally, ideating through artifacts led to insightful discussions with co-designers and the design group on current, local concerns. However, the introduction of speculative artifacts could produce futurist discussions and ideation amongst co-designers regarding matters of concern in the near-distant future.

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GOOD BENEFACTORS MANAGING DESIGN EXPECTATIONS

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ABSTRACT
Product design graduates can present themselves as over confident, unrealistic and even arrogant to potential clients. They seem to assume knowledge about their benefactors and have some false expectations of what it means to be a designer. Design courses should provide opportunities for students to explore their own background and experience. They need to develop an understanding the importance of social networks and be able to work with a wider range of organizations. It is vital that they understand the value of intellectual property and its central role in design exchange today. There is more than one design career route open to them and they must be able to change and adapt and be ready to take up opportunities. This paper is written from the viewpoint of a design historian and design manager, who has a fractional post teaching Contextual Studies on a Product Design course, at The University of Northampton, whilst running a specialist design consultancy. Those teaching design should learn to be good benefactors and manage their undergraduates' expectations.

Keyword: Product design, expectations, social networks, intellectual property, design ethics.

1 INTRODUCTION

Pip’s dream of a successful future was based on thinking his benefactor was the wealthy and eccentric Miss Haversham rather than being sponsored by an escaped convict. When he learns the truth he can adapt to the new circumstances because of his down to earth character, a strong social network and legal training.

I studied Charles Dickens' *Great Expectations* [1] in the classroom. I became fascinated with its soap opera structure. I drew a network that showed all the links between the characters in the story line. Whilst others were studying the language I was interested in the pattern of the story line, as well as the social context of the characters in the nineteenth century. I went on to study Sociology and particularly theories of social change and then an MA in Design History. The Master's dissertation [2] focused on the sociology of the gift [3][4] and studied how it was commercialized in Pip's time and 1950-1980 decades. Designers played a central role in this process in both eras. I have now been running a specialist research and design consultancy and teaching undergraduate designers for some thirty years building on this academic work.

The methodological approach underlying this paper is that of participant observation [5]. It is also a historical account and should be read alongside other accounts of changing teaching practice in the last twenty years [6]. It is about shared experience and the lessons that can be learnt from reflecting on teaching practice [7].

2 DOWN TO EARTH - KNOWING YOUR ROOTS

In higher education we aim to inspire another generation. To make sure our design graduates have great expectations which are not based however on unrealistic dreams or assumptions about their future career routes. Through my design practice I have been able to introduce young product or industrial design graduates to clients. I soon learnt that young male industrial designers [8] came over extremely badly at initial meetings. Time after time we either lost the opportunity to work with clients or the graduate on the team had to be replaced. I observed and changed my practice. Graduates trained as product or industrial designers were not introduced to new clients and were offered technical or support roles. What was the problem in giving them an opportunity? They came over as arrogant. They did not listen to the clients' needs. They patronized experienced sales staff. They lacked knowledge of manufacturing processes and constraints. They over-valued their ideas and expertise. If

they did not appear arrogant, then they lacked confidence and did not inspire managers to give them a chance at their enterprises. On the other hand, graphic designers and illustrators seemed to listen to the customer. It appeared to me that they were better trained and prepared to work more closely to answer a client's brief. They expect to be supplied with copy, images and brand information. In the textiles, fashion and clothing design specialisms there are fewer manufacturing processes and variables; the human body, clothing construction methods and dominant fashion trends, provide a shared starting point. Designers supplying images and surface patterns expect to work with art directors, graphic designers and on existing or standard products. Maybe what the consultancy was asking these product graduates to do, such as design small household products, new shapes for ceramics or plastics, structural packaging, personal accessories and toys was beyond the boundaries of their training. In some cases it seemed "beneath" their experience: craft, not Design or unworthy on some unvoiced way. The writings of Penny Spark [9], Judy Wajcman [8] on gender and design issues and the notion of craft and making in David Guantlett's *Making is Connecting* [10] have all proved valuable in my understanding of Product Design graduates attitudes and expectations. As educators we need to understand the social history of technology and how this has effected how and what we teach.
Design teaching needs to provide the skills to work in inter-disciplinary teams and in ever changing situations. In my practice, Vicki Thomas Associates (VTA), the client is often a trader or retail buyer without a design studio or even marketing team for support. As a design historian and a practicing design manager I bring a different perspective (as a sociologist, historian and as a woman running a design consultancy in the gift related industries) to the Product Design Team at Northampton. I have taught on the BSc course since it developed from an HND. The course started in 1994 and was based in within a School of Engineering and Applied Sciences, with staff contributing from aeronautical, mechanical engineering, mathematics, manufacturing and computing. The teaching staff had specialisms in engineering, plastics, recycled materials, timber and leather manufacturing. The course also drew on staff from the School of Business, where the focus in the 1990s was on training them to work be able to work outside the UK in the European Union with French language being taught. Links to the School of the Arts, where I was initially employed as a Design Historian were strong. The course emphasized sketching, drawing techniques, visual research and communication. It set out to integrate Art, Science and Business knowledge and from the outset the focus was on teaching through projects, ideally live ones from industry or competitions.
Like Pip, in the Dickens' novel who is an orphan brought up by relatives and struggles to know where he comes from a designer can benefit from have an understanding of their roots. Pip's surrogate father was a blacksmith, a skilled craftsman and metalworker. The Design History teaching has been about context of changing design practice. The first year curriculum teaches core academic research and writing skills, introduces sources of information and provides a history of the rise of the professional product designer. The blacksmith certainly has a place in that story. The module encourages an understanding of different historical approaches. It aims to develop the ability to discuss the variety of explanations of what design is and what design's role has been in society. There is a stress on the history of innovation in technology, materials and processes and in understanding how these developments have been taken up by industry and consumers to change the way we live. It differs in approach and emphasis from an Art History program. Nor does it focus on design theory, nevertheless, like any new discipline Design History [11] is informed by other academic subjects and approaches.

3 A STRONG SOCIAL NETWORK - RECOGNISING BENEFACTORS

When the course was written the second year Contextual Studies had a marketing emphasis and looked at the designers' role in contemporary western society. By 1999, our teaching at all levels had widened and the second year Contextual Studies was altered to encourage discussion of key areas of current practice such as cross-cultural design, sustainability, the global market, the effects of digital technology and knowledge transfer issues. We linked these topics for undergraduates with an exploration of ethical and legal issues. The aim was to generate awareness and provide a space in the curriculum for them to think through and discuss these issues among themselves. The focus of teaching had moved from expectations of design careers within the European Union primarily with industrial manufacturers and practices to preparing them to work with global partners in a wider range of creative industries and social enterprises. The studio projects were raising ethical issues and as staff we felt it was vital for their future careers that they reflect on their practice too and in the types of projects they tackled. An early graduate joined a firm designing gambling websites in Cyprus, one with Dyson at the time when production was shifted to the Far East, as well as others with local sign and plastic firms.

In the decade 2000-2010 the institution's structures changed as it moved to full University status in 2005. Theory, history and business were no longer outsourced from other schools. My line-management shifted to Product Design Course leadership and Contextual Studies became Design in Context. It was even more closely integrated into the course and linked directly with research and live projects. I was now an employee of the School of Engineering. Technological change was swift with hardware, software and the Internet all having an effect on delivery of our teaching and how we expected students to learn and work. Computers were also changing what was happening outside the University and expectations of designers in industry and business. The design process remained the same but the tools were different.

A Common Academic Framework was introduced across the whole of the institution splitting all courses into modules the expectation was that students would select modules from across disciplines. The Product Design course team felt strongly that the integrated nature of the course should be retained. Students could not opt in and out of individual elements. The course was redrafted into the required modules on paper but these were not open to any other students within the institution. For example, a business studies undergraduate could not opt for the Design in Context module, although this kind of cross-disciplinary work would have had its benefits. The teaching of the design process could not be split into parts and the context teaching was directly linked to projects when ever possible and was responsive to changes in emphasis.

At the end of the University wide changes these separate modules now described on paper, provided the underlying structure of a redraft of an Architectural Technology course and a new BA Interior Design Course. Trials were made periodically to share business and contextual modules but then a more tailored delivery was favoured and the groups were taught separately once again. At a higher level, Faculties and Schools were renamed and rearranged. Engineering, Computing, Leather Technology and Waste Management became a School of Applied Science and Product Design moved to an extended School of Art and Design - the only BSc - and were later joined by English, Media and Film courses, to become a School of The Arts.

Along with University status, academic research became important. As a design historian I had regularly given papers at conferences of my peers. Founded in 1977 Design History Society was mainly made up of lecturers teaching Design History at schools of Art and Design or on specialist BA or MA courses in the subject. By 1985 Design History was becoming more interdisciplinary drawing on the work of curators, business historians, social anthropologists and designers reflecting on their own practice.

As the Product Design team we had formed a small Design Research Centre led by Mark Wilkinson. We started bidding and responding to leads generated by the University's Knowledge Dock to collaborate on the Government funded Knowledge Transfer Partnerships (KTPs) starting with our first in 2002 with Datapride. This company wanted to set up in-house design capabilities and their initial project focused on an information/data booth for railway stations, a product now made redundant by 3G and 4G mobile telephone systems. For the next decade the team worked with on a wide range of projects under this scheme. Two housewares companies dealing with the design of imported products were introduced through my own practice networks. Three KTPs [12] had links with play and toy design. This led to further research and a successful impact case study in the Research Excellence Framework.

These play projects not only had external impact but they were valuable at an undergraduate level [13]. The benefactors and benefits were numerous. The grant income helped the firms innovate and provided a salary and vital experience for the KTP Associate, a graduate providing the conduit between the external organization (retail arm of Sue Ryder, a charity) and the University. The Associate provided a role model and mentor for undergraduates. Some Associates based themselves at the University one day a week sharing knowledge and research with staff. They worked actively with students on live projects from their partner organizations. The practice and knowledge transfer process was a reflective one. The educational experience was reported through publications. [14]

Many of these projects involved production in the Far East particularly China. This provided an opportunity to consider the ethics and practicalities of this sort of production. One or two projects ended early, in part because of changes in global trade. For Creative Tops (a melamine tray and placemat firm) United Kingdom ceramics import quotas were lifted making the need for new melamine and plastic innovation less of a priority for the company, as they could now provide ceramic products to complement their existing products. They reverted to a previous practice of offering different surface pattern on existing products rather than developing new shapes. In another KTP, a key railway carriage tender was won by another European country resulting in the closure of the UK manufacturing train-seating company who was The University's partner. Designing for a global market can be problematic. Live projects that do not run smoothly can also provide valuable experience.

Three of the KTPs were linked to the toy manufacture and play activities: Sue Ryder, John Crane Ltd and BCE (Distribution) Ltd. Designing playthings proved to be key to creativity and beneficial on a number of levels [15]. The undergraduates were involved with live projects, being able to share the experience of the Associate and working directly with the charity and company staff often at the highest level [16]. Designing for children made students think about designing for the future and for another generation. The safety standards for children's products are higher than those for adults so the importance of considering health, safety and appropriateness for the user was accepted without question. The importance of any story, meaning or values conveyed by any design could be understood as relevant to its successful marketing. They considered educational needs and intergenerational play. They sought out green and sustainable solutions. They played and through play became more adult in their design questions. They saw themselves as previous users and having something valuable to contribute from their own experience. The projects took them well beyond a brief to design an educational toy, which is often a standard task on product design courses.

Design research methodologies and processes are increasingly focusing on the social and having an understanding of human behavior and interaction [17] [18]. The business advisor from the funding organization of the John Crane KTP [19] asked whether more time should not be spent observing and playing with children. Being able to observe, listen and involve potential users at the generative stages of projects is seen as vital in much of the literature. Surprisingly in Sue Ryder and John Crane projects it was the adult user/consumer/purchaser who was key for the organizations involved. Toys are bought by parents and grandparents for children. It is about sharing time and experiences with their younger family members. Understanding the role of memory and the meaning of toys and play for different generations can be seen as important as observing how a new generation plays. Product designers need to learn to listen to the user but also to the client. They need to develop the skills of a social scientist and a trader as well as an engineer. Or they need to be prepared to work with them and understand their focus. The outcomes can be seen in some of the strongest final projects this year; a toy that helps communication between a deaf child and a hearing parent, the re-envisioning of a pond yacht and vivarium that improves the quality of life for the pet and a new business opportunity for the graduate. Specific data on the value to the graduate of this approach should be collected.

The students' drew on their own experience and reality of their own upbringing. The same is true of Pip in *Great Expectations*. He is given the opportunity to move to a different career in the City of London, but it is to his home-based networks that he looks for support. It is his misreading of the role of Miss Haversham in furthering his career that causes him to think he has higher expectations. Opportunities to work with benefactors through live projects or work experience is important. Pip’s view of his future was based on assumptions rather than knowledge. We have to create students with confidence of their own life experience and abilities. Expectations should not be focused on assumptions of their prospects of design careers in industry and consultancy practice.

4 LEGAL TRAINING - INTELLECTUAL PROPERTY

The emphasis used to be to prepare product designers to work in manufacturing industries or design companies. The professional practice modules on courses often centered on managing design companies not owning and running a broader range of businesses. Today designers are involved in a wide range of enterprises. The Mega Lab [20] study of consumers in US, UK and Australia indicates quite clearly describes a shift in manufacturing and consumption. Their study argues that there are two types of consumers "traditionalists" that look status and a good deal and the "NEOs" (New Economic Order) that look for value. The NEO's and the companies that serve them that are driving design innovation and economic growth. There will be a need for some designers to create mass produced products that make our lives function smoothly but this study that growth will come from more thoughtful products that are sought out and valued by their owners. We need to train designers to adapt to this new economic order and the firms that adopt this approach.

Designers need to be able to work in different cultures and countries with government agencies, social enterprises and charities. They need to be able to start their own businesses with the confidence to put ideas and research into product solutions that change lives. The University is an Ashoka U Changemaker Campus and leads on starting and managing social enterprises. This ethos can be seen in the students' projects in Product Design that repeatedly seek to improve the quality of life for the disadvantaged. New members of staff have questioned our industrial links and compared our teaching with other Product Design courses. Some courses have very strong links with international brands and major volume producers. We do have a hinterland of engineering, but it is specialist - lift engineering, motor sports, machine tools and model engineering. The leather industry is still internationally significant. Our studies of the toy industry [21] indicate the vital role the region played in the development of plastic production in the post-war decades. The region remains a key hub for production and distribution of a wide range of products from beer to signage. Understanding and developing social and physical networks are vital to a designers training today. As a design historian I have been using Latour's Actor Network Theory [22] to understand the role of design change in the past and the key difference that objects as well as people can make to a network. In the local context a rotary plastic molding process and tools developed by John Orme [23] made a whole range of new products possible from the road cone to the plastic football. Understanding networks and generating connections and collaborations on a local and national and international level is a key design skill.

Pip's chosen career was the law rather than that of a blacksmith. Product designers must have an understanding of the law too. Yes, for standards safety and regulations. They must be able to set up companies and draft agreements and contracts. They can buy in expertise but they have to understand what it is that they are delegating. They have to have their own ethical standards. In the last forty years the designer has increasingly seen themselves not as a craftsperson or a technician but a professional with all codes of behaviour and accreditation that that involves.

What do the design-led manufacture; creative industries, knowledge transfer and global brands all have in common [24] - valuable intellectual property (IP). In the thirty years I have been managing design projects it has been increasingly important to for us to understand IP. We now license our work rather than sell it. We add value to brands. The World Wide Web is encouraging sharing and collaboration and the sharing of IP. The music industry has been changed fundamentally music is shared for free on line and income generated through performance. Similar changes occurring in publishing books are all on line at a fraction of the cost of print and in education we are moving to on-digitized content. Consumers are buying books and music different formats. It is what they value that is affecting their choices. Products designers like drugs companies can make a huge investment developing their IP they cannot share or give it away without some recompense. Some firms are offer young inexperienced graduates offering freelance design posts and internships with no consideration for their IP. Some buy design outright offering a nominal fee and a credit when they know the work has a higher value in IP terms. Undergraduates and designers take short cuts and only use the Internet for research and self-publicity, without being aware of what they are using without permission and what they are giving away for free. In light of this commercial experience the Product Design Staff have responded to a funded scheme for the Higher Education sector, run by the Intellectual Property Office, to encourage graduates to learn more about IP.

The proposed project is to work with a Disney licensee in China, a vintage property in the UK and innovative design. The Disney Licensee's business is based on fashion accessories and leather goods, which link with the University's expertise. Issues of knowledge exchange will feature, with student being able to consider production in China for their home market. They will also create products for export to the rest of the world, particularly to countries where British brands are valued. They will gain valuable experience of developing and protecting IP as well as learning about the best way to use the work and property owned by others. Whatever the outcome of the bid IP will remain a central part of the contextual teaching at the University.

5 CONCLUSIONS - BENEFACTORS AND EXPECTATIONS

We have great expectations for our graduates but they must be realistic ones based on knowledge. It is a challenging and changing world and many will have to adapt to the needs of unexpected patrons like Pip's benefactor, the convict Abel Magwitch or in our case a Disney Licensee. Not everyone they will deal with now or in the future will share their values. Magwitch was a generous rogue and they will come across and have to learn to deal with clients and suppliers who have different expectations and attitudes. Judgment of character comes with experience and it is important that students have the opportunity to work with others, not only in design teams but also with a junior staff through to managing directors of major international corporations.

Good benefactors come in all shapes and sizes - from universities, through funding organizations to local suppliers. Graduates need to be confident about where they are coming from and have realistic expectations of their future. We have graduates working in a wide range of businesses, industries and social enterprises, as well as going into teaching and research; engineering knowledge and design skills provide only a starting place for a successful career.

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DEVELOPMENTS IN DESIGN PEDAGOGY

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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. This paper describes recent design education research by the author and others. It has taken a number of directions, focusing on the designer, the design context and the design interface. The end goal is programmes which are directed towards equipping graduates for entry to the community of professional practice. With the engagement of practitioners in the process, various teaching strategies can accommodate these approaches. The studio, tutorial, library and crit. are the traditional components, but using them effectively requires a deep understanding of the designerly way of knowing, and success depends on facilitating the agile navigation through the design process. Learning experiences should develop natural motivations to create a resilient, informed and sustainable capacity. Transformative learning is the key to gaining entry to the various practitioner communities. Each has its signature pedagogy and tutors support their students to become designers in ways specific to particular disciplines. They approach their teaching in qualitatively different ways, and engaging with the social practices and visual codes which constitute the particular design practice, illustrating them through case studies.. This can be approached by strengthening studio culture to provide safe spaces for creative and problem-centred learning and 'gateway' strategies of assessment. Key to sustaining motivation in this context is the toleration of design uncertainty as a threshold concept. Negotiating it successfully involves entering a liminal space in order to develop confidence and skills. Students need the time, space and structure to immerse themselves into a design brief, engaging in a reflective process to resolve the contradictions of a dual processing cognitive model. This work has been brought together in a recent publication which provides a synthesis and overview

Keywords: Pedagogy, design education research, Communities of Practice, CETLs.

1 INTRODUCTION

The work which is reported on here is based on the observation that in our universities and colleges the established approach to teaching design is through practice. For most students their ambition is achieving proficiency equivalent to designers in the professional world. Recent research into design teaching has focused on its signature pedagogies- those elements which are particularly characteristic of the disciplines. Much of the most productive work has been based on core design theory, although this has often been enlivened by philosophies and approaches imported to the area. Most importantly such work has utility when it recognizes the visual language of designing, the media of representation used, and the practical realities of tackling design questions. Increasingly the 21st century sees these activities in a global context where the international language of the visual artefact is recognized. Much of the work which has been collected together is based on studies undertaken during the period of special funding for centres of teaching excellence in the UK up until 2010. Two of those in design have provided the basis for research and innovative developments reported on here. They have helped to enliven the environment for design pedagogy research in other establishments which are also included.

Between 2005 and 2010 in England there was major funding for the development of teaching and learning in universities. The Centres for Excellence in Teaching and Learning (CETL) initiative represented the funding council's largest single funding initiative in pedagogy. It had two aims: to reward excellent teaching practice, and to further invest in that practice so that CETLs funding could deliver substantial benefits to students, teachers and institutions. [1]. 74 centres were funded across a range of universities, and within them a huge variety of types of pedagogic research and development was undertaken, across all discipline areas, much of it interdisciplinary and collaborative. The number of centres which had a direct location in design schools was small, 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. CLIP had the specific aim to identify, evaluate and disseminate effective practice-based teaching and learning in the context of the creative industries. Similarly CEPAD was specifically orientated to facilitating the creation of portfolios which provided access to the community of international industrial design practice. Since 2010 staff who had been involved in those centres have carried on with developments in these areas. Complementary work in other establishments is also covered to provide a compilation of related design education research and a synthesis of the approaches used.

2 PRACTICE BASED TEACHING

Both CLIP and CEPAD operated in contexts where the pedagogy is predominantly studio based. Traditionally art and design teaching is predicated on learning through doing, usually through the simulation of a professional situation by the means of a project brief. Students are neophyte designers engaged in the journey towards entering the community of professional practice of design. The approach which is typical of practiced based design teaching has a number of characteristics [2]. Students are from the outset practitioners, often with long periods on projects, usually calling for a number of technical skills and much activity is studio and workshop based. Assessment and feedback is usually through the 'crit' or 'critique 'augmented by much peer learning. With less emphasis on formal knowledge there is acceptance of open-ended solutions, varieties of practice and tacit knowledge. Students are expected to become independent, self analytical, critical thinkers, in an environment which does not emphasize theory, but does embrace key skills. Often a good proportion of the teaching staff are also practicing artists or designers.

3 FURTHER DEVELOPMENTS

This initiative to support a major investment in research and development for teaching and learning in English Universities with 2 centres where the pedagogy of design practice was a primary focus, served to embrace and utilise the idea of a community of practice, as providing the arena for effective teaching and learning. This had particular resonance for the pedagogy of design practice with its natural emphasis on utilising members of the relevant professional communities within the teaching and learning arrangements. It also gave a focus to realising the explicit ambition of students of achieving the means to enter such communities of professional practice. These can be seen to require particular arrangements for studio teaching with partnership working. For some the crucial ability is to travel through an uncertainty threshold to achieve the transformative learning which is a key component in a community of practice. The legacy of these initiatives is not only the implementation of curriculum arrangements which embody these developments but also continuing research into the pedagogy of design practice.

4 SETTING THE SCENE

Design education research has provided the basis for these developments. The development of research in design education can be through the designer, the design context and the design interface (3). Given the problematic nature of design education research, the essential requirement for continuous curriculum development and the difficulties of making effective research contributions in this context, it is important to provide a framework of key concepts. For example central to the notion of a 'passport to design practice' is the recognition of the existence of groups as 'communities of design practitioners'. (4). Where such communities are national and wear the badge of a professional body or society then they are easy to identify and quite visible. However there are other less formal international communities of design practice whose influence can be just as profound. Students who wish to become proficient as designers devote their time to engaging with design project activity. This develops in intensity and detail and as students become more experienced they are able to tackle progressively more complex design problems. Typically the end goal is that of achieving a level of capability to function as designers in the professional world. That is, they wish to become part of the community of design practitioners

The designerly way of knowing makes use of various forms of intelligence, particularly visuo-spatial thinking. It is a peculiar and complex process which typically addresses those questions which are not precisely formulated and developed, or ‘wicked problems’.(5) Design thinking involves the use of parallel lines of thought deploying serial and simultaneous cognition. Such a model is consistent with a ‘solution led’ approach and this is fundamental to its being a creative activity. Reflective practice is identified as an approach in which tacit knowledge can be deployed in reframing both the problem, and the solution. Various teaching strategies can accommodate these approaches. The studio, tutorial, library and crit. are the traditional components, but using them effectively depends on the approach being informed by a deep understanding of the designerly way of knowing. A number of key contributions are developed from this basis.

5 MOTIVATION AND THE LEARNINGSCAPE IN DESIGN

Designers are trained to deal with conflicting requirements and opportunities, and their ways of investigating problems and prototyping ideas are frequently aimed at exposing conflict to bring it out into the open. This requires a familiarity with a multidimensional landscape of design and designing (6) Developing motivation in design education today presents some particular difficulties and opportunities. Students can develop their personal motivation through strategies such as stimulating conflict, embracing failure and effective self-management that are sympathetic to design ideation and creative evaluation. In essence motivation supports effective creative and analytical thinking. The most powerful rewards in design are often those associated with being part of successful innovation, working as part of a team to successfully get a product into the marketplace where it’s well received. It’s here that undergraduate design courses can overlook such ‘emotional’ motivation and, even worse, create irrelevant reward systems. Garner and Evans make a case for prioritizing the development of motivation in young designers. This is all the more urgent as forces conspire to erode motivation by swamping design tasks with information. Designers need support for the agile navigation of the world of design. We need learning experiences that tap into students’ natural motivations but which professionalize motivation to create a resilient, informed and sustainable capacity. Since motivation is not one distinct force but is shaped and coloured by numerous cognitive forces and emotions, it seems logical that any attempt to develop motivation should acknowledge its diversity.

6 RELATING PRACTICE AND TEACHING: HOW SIGNATURE PEDAGOGIES SUPPORT LEARNING IN DESIGN

The characteristics which are required to prepare students for professions in design can be developed through engaging with the disciplinary ways of thinking, acting and being (7). Learning in the professions has particular characteristics which enable teachers to support their students to enter into the profession. These can be termed these ‘signature pedagogies’, ways to teach that enable people to develop disciplinary ways of thinking and being, or in other words, helping them to become certain kinds of professionals. These_signature pedagogies were distilled from the Landscapes project, which covered a range of disciplines. However, the principal of engaging others to learn to become part of a community of professional practice underlies the approach to teaching and learning in design. The principle of signature pedagogies provides a number of ways in which tutors support their students to become designers which are more specific to particular disciplines, but help to illustrate the concept of signature pedagogies. Many of the mainstream characteristics of design education feature as key ingredients, such as the studio environment, project work, the materiality of activity, professional dialogue, the critique and contextual project research.

7 TEACHING CREATIVE PRACTICE: CONCEPTIONS AND APPROACHES TO LEARNING LINKING VARIATION AND THE COMMUNITY OF PRACTICE

The conceptions of teaching held by academics in departments of design are linked to the conceptions and the communities of practice associated with the subject context.(8) This study focuses on the qualitatively different ways that teachers of design experience their teaching in practice based subjects in design. Much of the work that has examined teachers’ conceptions has built on research frameworks that also explored students’ conceptions and approaches to learning. The important feature of this analysis is the community of practice dimension, in particular how teaching is perceived as contributing to engaging with the social practices which constitute the particular design practice. The community of practice dimension is further explored in relation to how teachers may enhance the experience of learning and the learning environment by developing strategies which address the application of knowledge in practice based settings as well as their activity systems. Participation in a community of practice is a key premise to understanding learning to practice, including learning the values and appropriating an identity related to that practice.

8 DESIGN AND TRANSFORMATIVE LEARNING

Teaching design practice effectively involves a process of transformative learning (9). Becoming a successful designer depends strongly on individual capability to think in a designerly way, as well as the specialist design skills and knowledge to translate and develop ideas. Core to this is a process that requires the integration of both holistic and linear ways of thinking in a dual processing model, through engaging in practice. Typically this involves design projects, experiential problem solving and creative experimentation. Central to the approach is the development of mechanisms which help students to surmount a threshold of uncertainty. This is typically connected to the troublesome experiences that are encountered when engaging with design problems and solutioning. By embedding the activity in a studio-based culture that engages students through practice and experiential learning it can be handled effectively and productively. What is required is a learning environment, which overcomes the fragmentation that can occur on modular curriculum structures and provides most significantly 'safe spaces' for problem-based learning.

9 INDUSTRIAL DESIGN AND LIMINAL SPACES

The threshold concept theory posits the idea that within disciplines there are conceptual gateways or portals, which - due to their troublesome nature – can make it difficult for students to progress. (10) This notion of a threshold concept is seen as distinct from 'core concepts' – or building blocks – within disciplines, as it engages with the notion of transformation. Grasping, experiencing and understanding a threshold concept will irrevocably transform a student's understanding, and this transformation can relate to the particular subject. Of key importance is the concept of liminal spaces in relation to a creative curriculum. It is argued that for student designers, liminal spaces can be unsafe places as they will not have the skills, experiences and confidence necessary to negotiate them successfully and so a curriculum, which firstly identifies its 'jewels' and secondly builds safe spaces surrounding them can only enhance students' creative abilities. Design students need the time, space and structure to immerse themselves in a design brief in order to enhance their creativity and design solutioning ability.

10 DEVELOPING TOOLS TO SUPPORT TEACHING AND LEARNING IN THE USE OF SKETCHES, DRAWINGS, MODELS AND PROTYPES

Both design thinking and design communication make use of various forms of representation including sketches, drawings, models and prototypes which can be drawn together as a taxonomy indicating their varied functions.(11) Tools to support design education from 3D modelling to colour specification which have been validated through use by designers in professional practice are introduced to design studio teaching. Such tools are needed to overcome the barriers to communication during product development between industrial designers and engineering designers. The research was undertaken in four phases. Barriers to communication were identified through semi-structured interviews with industrial designers and engineering designers at a number of industrial design consultancies. The nature of design representations was categorised (as sketches, drawings, models or prototypes), and the differences in use between the two groups identified. By the use of a process of information design to translate the findings and data from Phase 2 into the card-based CoLab design tool that included the taxonomy it was possible to identify when the design representations were used by industrial designers and engineering designers and for what types of information. This has provided considerable scope for educators to integrate these resources into their teaching as required. It is a tool which illustrates both the disciplinary differences between the two communities of professional practice of industrial design and engineering design, and provides a basis for teaching strategies to deal with and capitalise on those characteristics.

11 LEARNING THROUGH CASE STUDIES

Case studies provide a rich insight into design proposals which are often grounded in real life and complex situations (12). It is argued that they offer the potential to understand design methods through good design practice when there is a clear context underpinned by sound empirical evidence. An audit of 223 design case studies in four of the leading design research journals with a detailed analysis of the type, subject and field of research provided examples to describe how case studies are employed within the curriculum to identify and draw out design methods and approaches. The research concludes with guidance on the use of case studies in design education. They have a very effective role in the development and acquisition of advanced, and professionally relevant, design skills and competences in the context of preparing graduates for entry to their community of professional practice.

12 AMPLIFYING LEARNERS VOICES THROUGH THE GLOBAL STUDIO

An understanding the construction of autobiographical processes is an important aspect of gaining entry to the community of professional practice.(13) A central part of constructing such a narrative is learning how to tell appropriate stories about oneself to prospective employers. Consequently it is argued that design students must learn to tell their own stories. The commonly utilised master-apprentice model which is highly useful in areas such as skills acquisition is not optimally effective in aiding students to tell their own stories. Other approaches are required if we are to equip future design graduates with the necessary reflexivity to be able to negotiate the increasingly complex world of the knowledge economy. The Global Studio aims to propagate a student-led pedagogic model in which tutors purposefully try to maintain their distance so as to encourage autonomy. The aim is to introduce learners to “complex project situations” and consequently to prepare them for contemporary working life. It is operationally different from “tutor-led” design education as lecturers are more “distant” in teaching and learning activities. Students construct conversations and outcomes primarily via interaction with peers..

13 CONCLUSIONS

Designers, for the most part, get on with designing, and leave design research to the academic community. One of the key questions this work addresses is whether or not there are links between design research and design teaching. Clearly the conclusion is that there are such links, and maybe they could be closer. The strand running through the work is that design research does support design teaching, and it shows a number of ways in which this is the case. This is a good reason for undertaking design research. If there is a close link with design teaching, particularly if design research supports effective design teaching, then that will gives design academics good reasons for doing such research.

Design education research has taken a number of directions, focusing on the designer, the design context and the design interface, each of which provides a useful agenda for developing such research. Many see the end goal as that of achieving design programmes which are directed towards equipping graduates for entry to the community of professional practice. This in itself justifies the engagement of practitioners in the process. Various teaching strategies can accommodate these approaches. The studio, tutorial, library and crit. are the traditional components, but using them effectively depends on the approach being informed by a deep understanding of the designerly way of knowing.

The community of practice notion is a major theme running through this work. The principal of engaging others to learn to become part of a community of professional practice underlies how most staff approach teaching and learning in design. Different design areas have their signature pedagogies and tutors support their students to become designers in ways which are specific to particular disciplines. Thus teachers may approach their teaching in qualitatively different ways, as it is perceived as contributing to engaging with the social practices which constitute the particular design practice. Participation in a community of practice is a key premise to understanding learning to practice, including learning the values and appropriating an identity related to that practice.

There is an emerging range of well researched proposals for templates for practice-based design education, aimed at producing graduates well suited to their various professional communities. Given the particular nature of the design disciplines there is a core need for the students to be enabled, and well motivated. In order to establish their identities as designers they will need to be able to tell their own stories. Such identities will relate to the particular signature characteristics and will depend on their having travelled through a transformative learning experience and overcoming the barriers which are particular to creative design practice. They will need to experience real world design cases with the visual language which is characteristic of different types of designer. The developments reported on here have been brought together in one volume entitled 'Design Pedagogy' to demonstrate how this can be achieved.

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TURNING INTERACTION DESIGN STUDENTS INTO CO-RESEARCHERS: HOW WE TRIED THIS AND SOMEWHAT FAILED

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ABSTRACT
There are many potential benefits of involving university students in research (as researchers, not subjects). It can help students to increase their retentive knowledge in the subject they study, and also develop research skills such as problem framing and analysis. While disciplines such as psychology and medicine have a tradition of students contributing to research publications, Design and Product Development does not. This indicates an untapped potential for researchers in these fields to more actively engage their students in their work.
In the spring of 2014, we made an effort to involve Interaction Design master's students in our research. It was in a Product Development course on "User Requirements Elicitation". The research itself dealt by comparison with the effectiveness of two research methods; namely, individual interviews compared to group interviews. During the course, students in groups made a quantitative and qualitative comparison of the two methods.
It was clear that the students did not appreciate this initiative. Their opinion was that it did not have a high enough "pay-off" in relation to their efforts. The course received very low scores when the students evaluated it. However, we could see quite clearly that they had developed an in-depth knowledge of the compared methods. The students also discussed issues such as reliability and validity of their research in a way that we had not seen in the course in its previous years. The whole experiment resulted in significant knowledge generation regarding how (and how not) to involve students in research.

Keywords: Co-research, student research, user requirements elicitation, research-based teaching.

1 INTRODUCTION

The relationship between education and research addresses a fundamental premise and philosophy that underpins the quality of teaching and learning in the modern University [1]. Inductive teaching, which employs research as a tool allowing students to learn by constructing their own versions of reality rather than simply absorbing versions presented by their teachers, is a key to learner-centered education [2]. "Student research" therefore, in both undergraduate and post-graduate level, has been described as "the pedagogy of the 21st century" [3]. Despite its importance, not many detailed definitions of what "student research" per se means, are available in the literature. The American National Council on Undergraduate Research (NCUR) defines student research as "an inquiry or investigation conducted by a student that makes an original intellectual or creative contribution to the discipline" [4].
There are many potential benefits of involving university students in research as researchers and not simply as subjects. From a learning performance perspective, it has been showed that it helps to increase students' grades [5] and that it helps students to develop a deeper [6] and more retentive [7] knowledge in the subject they study. Recent research suggests that students taught in lecture-based classes gain knowledge that decays over time but those taught with activity-based reformed methods (like research project-based learning) retain the knowledge they gain [8]. The research-based teaching approach helps students develop more general knowledge related to the research process itself, e.g. planning experiments, choosing methods, data analysis etc. [9], and it strengthens the bonds between

students and faculty [9]. Co-researching with students may also be beneficial for the researchers, as they get fresh and original ideas as well as extra manpower to carry out the work.

While it is difficult to find evidence of any negative effects regarding the inclusion of student research in taught educational programmes, there are some indications that it may be difficult to carry out effectively. The main barrier is often time constraints, as described by Buddie and Collins: "However, the overall picture that emerged from this research was that of an overtaxed faculty member who sees value in student research but who has too many professional commitments, too many research pressures, and not enough time" [10]

According to NCUR, there are four important steps in student research [3]:

- The identification of and acquisition of a disciplinary or interdisciplinary methodology.
- The setting out of a concrete investigative problem.
- The carrying out of the actual project.
- The dispersing/sharing a new scholar's discoveries with his or her peers.

In addition to this, there are also descriptions of what characterizes a good student research project [11]:

- Clearly-communicated purpose and potential outcomes,
- Well-defined objectives and methods,
- Substantial in scope (as opposed to a collection of small projects),
- Reasonable chance of completion in available time,
- Requires contact with the literature,
- Avoids repetitive work,
- Requires use of advanced concepts,
- Requires a variety of techniques and instruments (not exclusively library work),
- Culminates in a comprehensive written report.

Some disciplines have a tradition of involving students in research (and in particular in research publications) such as psychology and medicine. In the area of Design and Product Development it seems more unusual; the literature available is very sparse. A systematic attempt to identify academic journals dedicated (or somewhat specialized) on student research reveals that while there are journals available for a wide range of subjects, there is seemingly none on design related topics. This indicates an untapped potential for Design and Product Development researchers to more actively engage their students in their work, hopefully resulting in the aforementioned positive effects. This paper describes the experiences from such an initiative.

2 THE STUDENTS' RESEARCH PROJECT

In the spring of 2014, we made an effort to involve Interaction Design masters' students in our research. It was in our course on "User Requirements Elicitation", in which the students learned how to use methods such as ethnography, questionnaires and interviews to elicit requirements on products/services to be developed. The research itself dealt with the comparison of two qualitative methods; namely interviews and focus groups. The students were asked to assess their respective effectiveness after using them both.

As a first step, the students were given a number of scientific papers on the subject, as a means to provide them with deeper knowledge of the assumed relative merits of the different methods, as well as highlighting the fact that there still is a disagreement in the scientific community regarding the relative efficiency of the different methods. Furthermore, the papers negotiated the fact that the argumentation for the two methods differs in that those in favour of one-to-one interviews mostly argue from a quantitative standpoint, while those in favour of focus groups tend to have more qualitative (and considerably less quantitative) arguments for their standpoint. The papers were discussed in a literature seminar session that ended with the identification of a number of qualitative and quantitative measures for assessing the relative merits of the two methods.

During the course, students, in groups of four, conducted user requirement elicitation studies for a specific product/service system to be developed spanning from a bike-sharing scheme to a clothes pool. For the means of this study, it was mandatory to carry out a certain number of individual interviews (minimum five) and a focus group with the same number of participants as the number of interviewees. It was stressed that care should be taken to ensure that the participants of the two sample groups were as similar as possible. The material collected was then to be transcribed and analyzed in order to identify user requirements. Each group made a quantitative comparison of the two methods, based on data such as time spent, number of requirements elicited etc. Moreover, they did a qualitative assessment of the information gathered with the two methods, using an analysis plan developed by us based on the measures that were agreed upon at the literature seminar (see figure 1 – the analysis guide). At the end of the course, a concluding seminar was held for the whole class, where we comprised the data of all the groups, and discussed them together with the students. The discussion focused on the identification of the method that the students felt was the most useful for them as designers. Each group also wrote a short report on their comparative study, which was part of the examination process of the course.

Analysis guide

Efficiency

- Number of requirements that can be derived from the data
- Number of unique requirements that can be derived from the data
- Time spent on:
    - Arranging the interview(s)
    - Performing the interview
    - Analyzing the interview(s)

Quality

- Face validity – how useful as a departing point for product development you feel your results are?
- How were the needs expressed?
    - problems, solutions, requirements…
    - General/detailed
- What types of requirements could be derived? (Sort all requirements according to the Kano model)
- How did the participants interact with the mediating tools used?
- Were any group effects observable?

For the analysis of quality, start with a quantitative approach, i.e. count and arrange the statements according to the different qualities we want to measure whenever possible. Then make a qualitative analysis. In other words, we want to be able to say that "with method B five requirements that were classified as "Exiters and delighters" was elicited compared to only one with method A, which we interpret as method B being a better method if you want to elicit unique requirements that can lead to innovation" rather than "We felt that method B gave more "Exiters and delighters" than method A".

Good luck and don't hesitate to mail me if you have any questions

Figure 1. The analysis guide that was handed out to the students

3 OUR RESEARCH QUESTIONS AND METHOD

The initiative of involving the students in research was evaluated in terms of:

- Quality of the conducted research.
- The students' knowledge development of the course topic.
- The students' development of research skills.
- The students' experiences and perceptions of the research initiative.

Furthermore, the goal was to provide some explanations on why these effects occurred, and show implications for future initiatives of a similar kind. In order to evaluate this, the following data sources were utilized:

- Direct observations of the students during the course process, made by the faculty staff involved in the course (the examiner, a lecturer/supervisor and a course assistant).
- A course evaluation consisting of an anonymous survey.
- In the research seminars during the course, part of the time was spent discussing the students' views on the research process and how they experienced it.
- The examination of the course consisting of a written exam, a report and an oral presentation.

4 RESULTS

The results of our study have been organized in sections answering the following four questions: 1. What was the quality of the conducted research? 2. What was the outcome in terms of the students understanding of the subject compared to previous years? 3. What was the outcome in terms of the students understanding of research and the research process? 4. How much did the students appreciate taking an active part in research? It should be noted however that this paper does not intend to provide an analytical record of the students' results but instead document the insights of a first-time educational experiment that the authors conducted with their course as a way to promote Chalmers University of Technology's initiative of research-based learning.

4.1 Quality of the conducted research

The quality of the research, in spite of us having created a fairly strict scheme to follow, differed between the groups. While some of the groups did come up with a large number of requirements (100+), others identified much less. There were also different opinions and experiences between the groups regarding which method of the two provided the most and/or the best quality data. These differences could not be easily explained by any other means than the differing qualities of the students as researchers (e.g. some of them being more systematic than others). Nonetheless, despite these inconsistencies, the authors which are all active researchers with a significant experience in qualitative research methods, after carefully reviewing the material submitted, feel that the combined results with the right treatment are of publishable quality and they are currently preparing a journal paper submission dedicated to them.

4.2 The students' knowledge development

Looking at the students' reports and presentations it is clear that there were some improvements compared to previous years. Similarly the discussions at seminars, not only the ones discussing results, but also the literature one, were more in-depth than ever before. Some examples of topics that were discussed more apprehensively during this year's course include:

- How even the slightest changes in data collection method will affect the collected data.
- The efficiency of different methods, i.e. how valuable they are in relation to the efforts needed.
- The importance of eliciting the 'right' requirements and not just as many as possible.

Understanding in real terms the strengths and weaknesses of the two aforementioned qualitative research methods in design is not a simple textbook-based learning process. On the contrary is a demanding process requiring a hand-on approach of systematic comparisons between the two that can be achieved only through practicing both in similar conditions. The more thorough one is in organizing, conducting and analyzing the interviews the better results one gets and the more one understands what contributes to these findings. The demands on rigor in order to fulfil the "research-conducting" criterion forced the students to make a better job at eliciting requirements and as a consequence allowed them to develop a better theoretical and empirical understanding of the subject. The students also learnt more about the existing state-of-the-art knowledge in the field.

4.3 The students' development of research skills

Not very surprising, the students' understanding of research improved. For most of them this was the first time they employed a more systematic and comparative research approach. Having on-top of that to actually provide an in-depth comparison of the two compared method allowed them to retrospectively look into a process they had just experienced from an evaluator's point of view. Some examples of topics that were discussed more apprehensively during this year's course include:

- The quality of earlier conducted research in the field.
- The quality of their own data collection in terms of reliability.
- The quality of the comparison made across the different student groups' data in terms of validity.

Thus, we found improvements in the students' estimations of their results' (and others) value and generalizability, compared to students taking the course in previous years. In particular, we saw our students in 2014 taking a much more critical view on their studies and on the research presented in the papers they had read as part of the course than any year before that.

4.4 The students' experiences and perceptions of the research initiative

Despite the conclusion that the students developed a more thorough understanding than any previous students taking this course before, the student's evaluation of the course did not reflect this outcome. The course got an all-time low score. While the overall rating usually is in the 3,4 to 3,8 range (on a 1 to 5 scale), last year's score was 2,2. The main objection from the students seemed to be that they felt used, and that their efforts did not contribute enough to the learning objectives of the course, as illustrated by the following quotes from the course survey:

"The course only seems to focus on forming a basis for Wallgren's research."

"After taking this course, I have strongly begun to doubt the credibility of academic research in general. The course must focus on the student's learning objectives and not Pontus himself."

5 DISCUSSION

The initiative to involve students in research resulted in the positive effects that have been indicated in earlier research. Although it is not possible to identify precisely the magnitude of the effects, it is clear that there was an increase in knowledge development among the participating students at this year's course. However, while we as teachers saw these effects, the results of the course evaluation indicate that the students did not. To some extent this is expected, as they did not have the possibility to compare the outcome of this year's course to earlier ones. Still, it is clear that the students generally did not appreciate the research initiative; even if some students did see some positive effects, they did not think the learning benefits were representative of their efforts.

If compared to the nine recommendations provided by the ACS Committee on Professional Training [11] (presented in 'Introduction'), this research initiative basically fulfilled all of them. The research task had a well-defined objective, was clearly communicated, had a reasonable work load etc.

The negative experiences seem to be more connected to how the research task was embedded in the course, and the roles the students had in the research process. There are four aspects of the overall set-up that seem to have had a particularly negative impact on the students' experiences:

1. The research task focused heavily on data collection and analysis, and not on the early phases of the research process (problem identification, choice of method etc.), nor on the later phases (publication and sharing results).
2. The students were not voluntary co-researchers; it was obligatory for all the students in the course to carry out the research task.
3. The relationship between the students and teachers was not 'collegial'. The teachers were clearly in charge of the main decisions in the research process.
4. The teachers were open about potentially using the students' research project results for complementing their work in comparing interviews against focus groups; they even asked whether some students would be interested in co-authoring an eventual paper. This was the ethical approach to take, and was used as a motivational strategy aiming to make clear that their work was of actual research significance, good enough for the means of publishable academic research. Despite these intentions, the 'openness' seemingly undermined the whole 'learning through research' framework of the course making perhaps the students to feel that they do extra work for their teachers' sake that could have easily been avoided.

Most of these problems arose from the course context, i.e. the course conveyed limitations for how the research task could be organized. For instance, there was limited amount of time available, and there were a relatively large number of students to carry out the research. In addition, the research task needed to be aligned with the learning objectives of the course. All this resulted in a research task that was heavily guided and steered by the teachers and not the students. While the students may have shown a greater interest in a research task that could be of their own choice, it could have resulted in problems of keeping it contained within the course structure. Furthermore, the number of students also called for heavy guidance of the research task. As all the 25 students could not form a single project group, they needed to be divided into smaller groups. This in turn made it necessary to make sure that the data from all groups were comparable and could be used to make scientific claims. Yet another reason for the heavy guidance was the students' level of knowledge at the start of the course. Identifying relevant research questions within a field generally requires a relatively deep knowledge of it.

The course context also brought along another important issue; the students' expectations. Their main objective was to partake in the course, and not develop themselves as researchers. Although the research task helped them to reach the learning objectives of the course, a lot of them still viewed it as a detour on their way towards passing the course as efficiently and effortlessly as possible. Unfortunately this also resulted in some of them feeling used by the teachers, as they though the main purpose of the research task was to favour the teachers' personal research careers.

6 IMPLICATIONS AND RECOMMENDATIONS

Although the results of the experiment were particularly encouraging in terms of knowledge generation and research skills' development due to the all-time low course ratings of the student evaluation there will not be a continuation of the course in the current form. Teachers at our university are evaluated based on the students' course ratings and as teacher one cannot afford to get such low scores for an extended period of time. We will revert to a course more similar to previous years where the students do projects of a more applied character. A smaller comparative study will be conducted within the project and every group will get their own supervisor to try to influence the students so that the studies get higher reliability, which may make the results possible to aggregate to something useful over time.

In general our advice for teachers wanting to do research with students is the following:

- If it is part of a course, be aware of the challenges this conveys. In particular, be aware of the students' expectations and try to make the research-based part of the course its main objective, rather than something they perceive as "extra work"
- Make them true co-researchers. Take part in the "simpler" tasks yourself and let them take part in the more advanced tasks. They will learn more by actively working with you, than by merely cooperating with you through an asynchronous division of the work in the research process. This will also have a positive effect on the scientific quality of the research, which may suffer if the students work on their own.

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EDUCATING DESIGN PROFESSIONALS IN THE 21ST CENTURY

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ABSTRACT
Recent research indicates that skills, knowledge and creativity (SKC) share equal importance for professional designers (Guo, 2011). This is also true of graduate designers (Zerillo, 2005). The design of the curriculum, teaching, learning and assessment strategy is therefore crucial in preparing students for professional practice.
An experiment was conducted to identify whether the current BSc Product Design Engineering (PDE) programme offered by Liverpool John Moores University (LJMU) adequately prepares students for employment in the design industry. The findings showed that the current programme's design and teaching and learning approach needs to be re-evaluated if it is to satisfy students' intellectual growth and prepare them for careers in the product design sector.

Keywords: Product design, design education, industrial design, product design engineering.

1 THE CHANGING ROLE OF DESIGN AND ITS IMPACT ON EDUCATION

Porter (1998) provided a theory as to why some nations are more competitive than others, and equally why some industries are more advanced than others. The model of determinant factors in national advantage has become known as "Porter's Diamond" (Figure 1) which suggests that the 'home base' of an organisation plays an important role in shaping the extent to which it is likely to achieve advantage on a global scale.

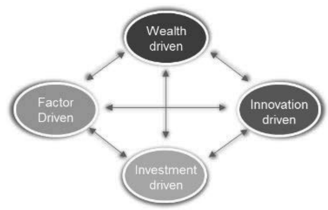

Figure 1. Porter's Diamond (Porter, 1998)

If one applies a representative example of the business planning and design process to the different stages of Porter's Diamond model the resulting output suggests that 'design thinking' has an increasingly significant role in informing business strategy at successive stages. Since much of Western industry is at the innovation-driven and wealth-creation stages of Porter's model, design might be expected to play a key role in business development with clearly outlined objectives. In contrast, the emphasis is placed more on infrastructural changes in developing countries.
Consideration of the business versus design processes model across these stages illustrates the dilemma facing design within emerging economies. Often, design is perceived to be of little benefit to business strategy at earlier stages of economic development, where primary concerns are the exploitation of manufacturing capacity and the development of capability via technology transfer and skills development. Innovation is often not recognised and contributes little to an economy focused on 'catch-up'. In this scenario, industry – especially at senior management levels – is unlikely to perceive value in design and will be unlikely to contribute to its development as a profession with status equal to other disciplines such as management and engineering (Williams and Guo, 2006).
Given the observations above, it is apparent that design plays a different role in the different phases of industrial development. In a developed economy design informs strategies in business planning and

creating more diverse roles and career opportunities; whereas a developing economy design is perceived as having low value.

Cooper (2004) represents the evolution of the role of design as a timeline within New Product Development (NPD) that in the 2000's design came to mean:

- creative: driving a more central role for designers (Stamm, 2003)
- holistic: incorporating a broader array of tasks to support the whole NPD effort (Turner, 2000)
- direct generation of customer information (Leonard- Barton and Rayport, 1997)

She also outlined the skills that required by contemporary role of design include:

- functional specialism: traditional design skills and aesthetics, visualisation and technical skills
- team-based abilities: interfacing and communication skills
- design-centred abilities: business, research and observation; and project management
- multidisciplinary-thinking and knowledge-transferable ability

Together with in-depth knowledge in respect of:

- design issues (e.g. aesthetics and human factors)
- manufacturing (e.g. material and manufacture processes)
- brand and business strategy awareness.

Within the context of reducing local manufacturing bases in Europe and other regions (Curedale, 2003), it is anticipated that there will be an impact on the demand for traditional product design skills. This may lead to a change in the profile of students from a vocational to a more academic orientated skills set. The UK in particular operates a mass design education policy which requires a thriving student population and design industry in order to survive (Bolton, 2006).

The service-based UK industry focuses on branding and service design; which requires research and conceptual thinking skills; hence education may cover broad range of SKCs, but avoid over emphasis on industry- based skills, e.g. packaging and retail promotional design skills (Bolton 2006).

A decline in the number of undergraduate product design courses has led to increase 3D design courses and post graduate programmes (Bolton, 2006). It is proposed herein that design in higher education should seek to balance skills, knowledge and creativity whilst respecting both student and employer aspirations and expectations.

Given the above state of design in both industry and education, educators need to ensure that their design-related programmes of study meet the aim of producing work-ready product designers. It is therefore paramount that the design of such curricula is done with the aim of improving and enhancing the teaching and learning approaches within a programme.

The principle aims of this research are twofold. Firstly the authors propose a link between industrial expectation and graduate competencies as measured through the metrics of skills, knowledge and creativity. Second we examine the existing competencies of a small sample of current students at this institution as measured against industry expectation. The output of the experiment herein shall be used in creating a new MDes programme designed to "fill in the gaps" identified through this research.

2 INDUSTRIAL EXPECTATION

Expectation in Western higher education institutions and industry appear to differ, as graduates struggle to satisfy their employers' desire achieving good academic standards. Design graduates are full of ideas, but they often do not fully understand client needs.

Employers cannot find the right level of really good skills right across their companies in the UK (Sands, 2009). A significant number - 21% - of design consultancies interviewed by the UK Department for Education and Skills in 2002 said they were 'not at all satisfied' with the skills of the graduates they were employing (UK Design Council, 2005). It is getting worse in general according to a recent investigation (BBC News, 2013). 52% of UK graduates lack employment skills, in particular communication and team based skills. Just 20% of employers believe that the graduates they recruited possess suitable employment skills. Aside from a lack of design skills, literacy and mathematical ability, they pointed to a lack of business awareness. Employers suggested more use of visiting lecturers and studio-based activities, including the type of collaborative and team working that is common in consultancies (UK Design Council, 2005).

Consultancies in the US seek technical skill sets that can add value to the team and produce fee-based hours of work. Companies generally look for someone who can quickly cement a position on the team, they do not like to recruit students and then spending time on further training, as training people is expensive, and by the time newly hired employees are productive, they usually leave to get a better job.

In today's cost conscious world, technical experts are necessary to leverage efficiencies in each item on the assembly line. An in-depth knowledge of production methods and markets at each stage of the NPD process are considered pillars of appropriate design. Understanding the means of production includes interpreting a client's instruction or design brief. Design skills, knowledge and creativity are essential, but not enough. The ability to manage, liaise with clients and apply real-world experience are also considered essential skills by most employers (Zerillo, 2005).

3 EXPERIMENTAL PROCEDURE

An experiment was developed and run within the BSc Product Design Engineering Programme at Levels 4 and 5 in the School of Maritime and Mechanical Engineering, April to May 2013 with the principle aim of measuring student attainment against the design industry's expectations. Although we acknowledge the sample size for the experiment is very small, we are necessarily restricted by the size of the respective cohorts given that we are specifically analysing LJMU's Product Design Programme in respect of the aforementioned metrics of skills, knowledge and creativity.

The experiment aimed to identify how well students apply knowledge and skills at each level. Additionally it explored whether the current curriculum design helped the students' intellectual growth in terms of skills, knowledge and creativity, in respect of the following:

- Research skills
- Visualisation/presentation skills
- Communication/leadership skills
- Material/manufacturing knowledge
- Product semantics/ ergonomics
- Product aesthetics knowledge
- Awareness of branding
- Multi-disciplinary thinking ability
- Creativity

The above competencies are embedded into existing mark schemes at levels 4 and 5. Thus, when students are graded in their coursework they are effectively marked against industry's expectations. In other words, the experiment is a relative measure of student skills, knowledge and creativity against industry's requirements.

The theme for the experiment was that of a mobile phone design. This was chosen as it is a common product that almost everyone can associate with and is of relatively low complexity (in terms of design) and higher complexity in terms of functionality, product identity, user lifestyle and ergonomics.

Eight students were invited to undertake the experiment supervised by the author[1]. There were two teams of two students at each level. The students were representative of each level in terms of their academic ability. The total project duration was 10 hours. To help keep students focussed on key criteria, decisions and activities this total time was broken down into five two-hour sessions. Questions were posed at the beginning of each session to prompt participants to engage in the planned activities.

4 ANALYSIS OF RESULTS

Figure 2 shows that the level 4 students possess similar levels of knowledge and skills. It is also noted that the performance of each pair of students was identical in the following areas: visualisation, communication, leadership skills, material/manufacturing, product ergonomics knowledge and multi-disciplinary thinking ability.

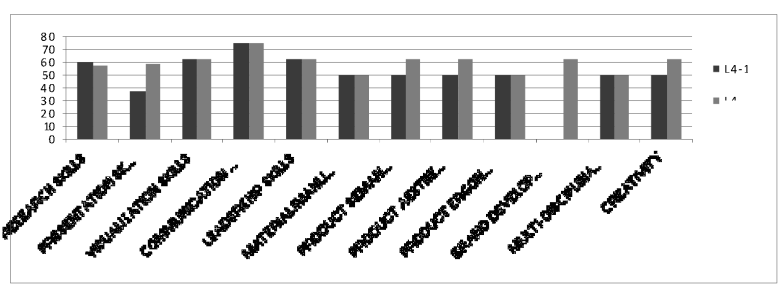

Figure 2. The comparison of two group of students' performance at level 4

Significant differences are observed in the areas of product semantics and aesthetics knowledge and creativity, in particular presentation skills and brand development knowledge.
One explanation for the difference could be that the students have different academic backgrounds - the subjects that the students studied pre-University where, typically, presentation skills, aesthetics and brand development would be taught as part of a subject such as art or design.
If a baseline of 60% is taken as being a good standard for each area assessed, the results also suggest that most students have a good level of skills such as visualisation, communication and leadership, knowledge of materials, manufacturing, product economics and multi-disciplinary thinking ability. The latter two may have been obtained before entering higher education; the former two via modules delivered as a part of their programme of study at LJMU.
In contrast it is evident that students demonstrate a significant difference in most aspects at level five (Figure 3). From this data it could be deduced that the HE provision at level five in some areas hindered students' intellectual growth. One possible cause for this is that the teaching and learning approaches were not appropriate in respect of meeting this goal.

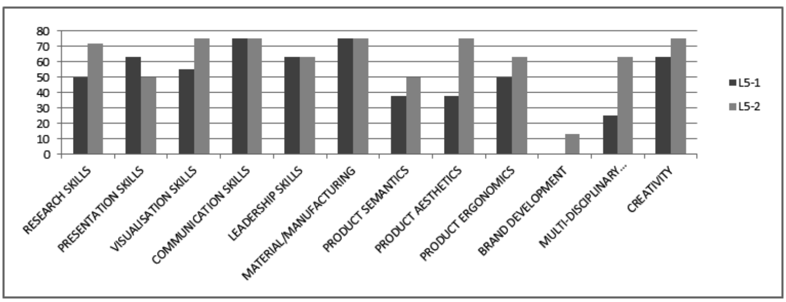

Figure 3. The comparison of two group of students' performance at level 5

As can be seen from Figure 4, it is evident that students' skills and knowledge incrementally grow from level four to level five. Significant gains are shown in aspects of research and visualisation skills, product ergonomics knowledge and in particular, presentation skills, manufacturing, product aesthetics and creativity. Thus, the students apparently show good intellectual growth between levels 4 and 5 in these areas.

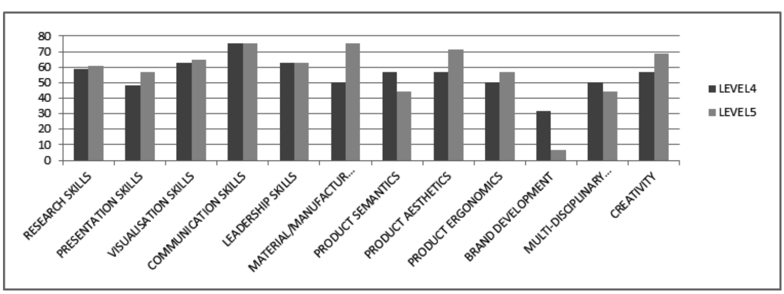

Figure 4. The comparison of two group of students' performance between levels of 4 and 5

However, a number of anomalies are apparent in communication and leadership skills: the students appear to demonstrate no significant progress between levels. Other retrograde changes are apparent in aspects of product semantics and brand development and in multi-disciplinary thinking, where there is a clear decline between levels four and five. It appears likely that these areas are not being adequately covered in existing modules.

Issues arising from the preliminary results include:

- Level 4 students may have different academic backgrounds, pre-University
- Level 5 students perform significantly differently after almost two years study within the current programme
- Some students at level 5 made no progress and even regressed in some areas.

The above results suggest that the current programme design and teaching and learning approach will need a rethink if it is to satisfy the students' intellectual growth in future. The development of a new curriculum and teaching and learning methods should perhaps take students' prior knowledge into account rather than simply relying on tutor's own experience and knowledge (Prosser and Taylor, 1994).

Research indicates that a skills-driven programme emphasises skills-based teaching, matching the graduate with the existing needs of business. This approach is more suitable for manufacturing-based economies. In contrast, a knowledge-driven education that values student career aspirations is designed to satisfy a student's career sustainability and also meet the *long-term* needs of business (Guo, 2011). Thus the educator serves two masters: students and business (Zerillo, 2005).

The UK's service-based design industry has evolved with an emphasis on brand, conceptual thinking, design strategy and management which requires a broader range of skills and knowledge, and demands graduates work on activities as part of a team (Bolton, 2006).

5 CONCLUSION

Reflecting on the results of the experiment and specifically in regard to LJMU's PDE offering, it is the authors' contention that, in order to fully satisfy both Western (UK) industry needs and students' career aspiration, the existing three-year programme may not be the ideal vehicle in producing graduates with an ideal balance of skills, knowledge and creativity. In order to endow students with that balance, a new postgraduate programme is proposed.

The new programme should equip the students with not only the ability to design, manufacture and test design solutions; but also with a firm knowledge of business strategy and branding with provision for appropriate work experience. On completion of the course, students should have acquired an in-depth knowledge of research methods, project management, leadership skills, brand and business strategy awareness and multidisciplinary thinking. This should fully prepare students for high-flying product design oriented careers in the knowledge-driven economy of the 21st Century.

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Chapter 6

Ethics

QUESTIONS OF VALUE - ETHICS IN THE DESIGN CURRICULUM

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ABSTRACT
Decisions made by designers multiply in their consequences, as products are mass-produced. With changing designer roles addressing systems, services and symbols the questions of value a designer faces also grow. The Ethics of Design is gaining new importance, and is again frequently discussed in literature. This article discusses educational challenges and opportunities equipping design students with knowledge and skills in exercising informed judgement about questions of value. To elucidate how ethics is dealt with in (higher) design education, the authors reviewed perspectives on ethics and its role in education, interviewed 6 program directors, and based on reflections from these employed insights in a workshop with design students.

Keywords: Decision-making, values, ethics in design curricula.

1 INTRODUCTION

1.1 Questions of value in design

Ethical issues in design are getting more attention than ever. Commodities are mass-produced and globally used, and decisions made by designers multiply in their consequences. The design professions are gaining increasing influence in society and designerly methods are frequently applied in other areas [1]. With these changing roles addressing systems, services and symbols, the questions of value a designer faces also grow. The Ethics of Design is here gaining new importance, and is again frequently discussed in literature e.g. in the fields of graphic design [2], design for sustainability [3] and Human-Centred Design [4].

Addressing ethics implies addressing people's values and beliefs. While having values, norms and ethical attitudes are a part of the human condition, and the human challenge is to understand what is right or wrong and act accordingly, the task for a designer is to learn how to recognize values and norms, how to decide which have to be met and how to realize them in a product or service [5].

One way of categorizing existing perspectives on ethics in design and design curricula is to see them within three dimensions [6].

1. Ontological i.e. concepts and approaches that discuss the designers' role and responsibilities: 'designers as moral beings'.
2. Epistemological/methodological i.e. in relation to the design process and its trade-offs, e.g. tools and or methods that consider ethical aspects such as ethical decision-making
3. Practical i.e. in relation to 'ethically' correct products and services, such e.g. recycled or energy saving products, social entrepreneurship etc.

1.2 Ethics

On a general level, several perspectives can be taken on ethics. Ethics comes from Greek "ethos" way of living, and concerns theories about moral action. For example: Do workers in the 3rd world have the same labour rights as workers in the 1st? If yes, is it then right to buy cheap clothes?

While ethics is theoretical, moral concerns practical decision-making. The term moral comes from the Latin "mores" and means "custom", "lifestyle". It is a decision about the right action. For example: When I believe, that all workers have the same rights and nevertheless want to buy cheap clothes, I have a moral problem.

Western moral theories or ethics can be structured within in three areas: meta-ethics, normative ethics and applied ethics [7]. Meta-ethics examines the origins or sources of ethical principles and provides definitions of ethical concepts in order to understand what can motivate moral conduct. Normative ethics takes a practical role in forming theoretical moral standards to regulate right and wrong conduct. The main meta-ethical concepts are shown in the following table:

Table 1. Ethic theories [8]

Position	***Type***	***Criteria of moral action***
Teleological: Moral actions must have a goal	**Utilitarism** (e.g. Bentham, Singer)	**Happiness**. The most moral action gives the most happiness to as many people (beings) as possible. Example: Everybody shall have the possibility to live a good life.
	Eudaimonism (e.g. Aristotle)	**Good Life** Moral actions are those which contribute to a good society.
	Ethics of Responsibility (e.g. Jonas)	**Minimising harm.** In case of doubt one has to skip an action until the consequences are known.
Deontological Moral actions are independent from actual circumstances and universally valid.	**Ethics of Justice** (e.g. Rawls)	**Justice.** The criterion for morally right action is a hypothetical test, where the participants decide only by criteria of general human interests.
	Ethics of Duty (e.g. Kant)	**Categorical Imperative.** The criterion for a morally right action is if its maxim is universal applicable: "Act in a way that the maxim of your action can always become a general law."

Applied ethics examines and resolves specific controversial issues by using the conceptual tools of meta-ethics and normative ethics. Contemporary examples of applied ethics in design are, besides the fields mentioned above, consumer and -marketing ethics [9] and 'technoethics' [10].

1.3 Ethics in the curricula

National Higher Education (HE) regulations in Sweden [11] and Norway state that students should be demonstrate understanding of societal and ethical aspects. Norway's National Curriculum Regulations for Engineering Education declares: "The education is to facilitate and safeguard the interaction between ethics, environment, technology, individual and society" [12]. Realising the objectives may however be challenging. Despite regulations like these, the issue of students' ability to contextualise their work have been an issue on which many Swedish design programs received negative comments in the quality assurance evaluation [13].

Some key aspects that have been discussed in literature in relation to addressing ethics in the design curriculum are: a) Raising awareness and understanding of ethical issues in (engineering) design, partly through theory and partly through practical projects [14] b) Fostering justification of arguments [15], and c) Developing strategies and methods for ethical judgements in design trough practical assignments [16].

1.4 Aim

HE needs to prepare students for addressing ethical issues, but is HE really prepared to do this? This article presents a step within a wider series of activities aimed at addressing reflections, starting points and ethics in design research and –education. A first aim is to examine how ethics is addressed in design education, with a focus on overall curricula. A second aim is to identify practical educational challenges and opportunities equipping design students with knowledge and skills in exercising informed judgement about questions of value.

2 THE INTERVIEW STUDY

Comprehending how current design HE actually work with education on ethical questions, we conducted interviews with 6 program coordinators from Swedish and Norwegian universities, each lasting roughly 30 min. Participants were asked about ethics in the curriculum (e.g. how well prepared the graduating students were, Teaching and Learning activities, Intended Learning Outcomes, Assessment tasks), as well as their understanding of the relevance of ethics to the design professions. The interviews were recorded, and transcribed into summaries, which served as a basis for a bottom up content analysis.

The interviewees all claimed to address ethics within their programs, though some admittedly think they could do it in a more informed way. The primary topoi of relevance seemed to be environmental and social issues. In addition, several participants expressed ethical concerns when becoming professionally involved with topics such as designing for weapon and/or tobacco industry.

2.1 Ethics in design

There seems to be a general agreement that ethics is important to design, exemplified with a general assertion that 'Designers are a relatively engaged group of people who are used to raising questions'. Furthermore, participants emphasised a designs relation to ethics: 'You have to understand people- be somewhat of a thing-psychologist'. They also described a general assumption about making things that are positive for people on basis of societal values: 'You are indoctrinated in the well and woe of users'. This also influences the students: 'It is surprising how fast the new students adopt the design role model and realize the responsibility that lie in developing products and systems at based on users and society's conditions'.

Several of our informants put forward explanations for why design might hold a special position: describing e.g. how: 'It has always been important for designers to understand the target group/…/ it has always been like that, empathy long before these ethics discussions'. Two participants made claims about designers possibly through the holistic of the profession may be especially sensitive. Furthermore it was put forward that the design profession has lively ethical discussions, and that this also applies to HE: 'Design education is strongly anchored in ethics, stronger than in other disciplines /…/we talk about the aesthetics of systemic design /…/ethics and aesthetics are closely linked, and respect and humbleness are important values'.

However, as described by one of our participants there is a general consensus that 'Designers should make the world a better place to live in, not work for maximizing corporate profit', but that taking the next step may be more difficult. A key challenge brought forward by some of our participants was the scope of questions discussed and the students' comprehension. Participants commented that 'Everyone wants to be on the good side'. In several cases they mentioned on how explicating one's position was not only important for one self, (s)he in many cases also need to collaborate with others, why one in some cases have to be careful about becoming associated with certain types of products. Being explicit, was stressed as even more important in a commercial context: 'In the comfort of the Uni you can afford to be different compared to the commercial world'. Another notes 'Designers work a lot with intuition, there is a risk of not being able to explain the underlying intent'. The participant further explains how this is a problem when designers to an increasing degree work in teams. A need for making arguments explicit was noticeable in relation to professional roles: 'When you work in practice you need to argue, you have to be able to convince- feeling is not enough'.

Other participants stress a need to straighten out one's position in advance in order to be able to make a difference; 'My experiences as a practicing designer is that ethical questions can come very surprising /…/ If you haven't then thought through your position, it is easy that someone else takes the decision, that the window of opportunity for influence closes'.

2.2 Learning ethics in design

One of the participants described how the typical early revelation for students is that they are part of consumption society, but that their understanding is typically at least initially limited: 'They think they are well prepared because it is a theme they have heard a lot about and are familiar with'. Others commented on how some issues tend to become one-sided; that questions are so to speak already solved, and that it becomes more interesting when there is a diversity in positions: 'Students should become aware of conflicts of interests- They need to see that questions change over time and that there is not ONE answer'.

Our informants also commented on the degree to which students engaged with issues, stressing e.g. the importance of making students aware that opinions may differ- and the importance of taking a stance. One participant described ethics as ’Subjective- what feels right’. Another describes how some students struggle with ethical, issues and in some cases get provoked, while ’Others have a strict academic relation to it’.

2.3 Teaching ethics in design

Several of our participants commented that ethics is often thought of as taught implicitly; ’Would like to think that the students are well prepared upon leaving college /…/there seems to be an assumption about this as something we know and do without a need to be very explicit’. Teaching ethics may be challenging for various reasons; e.g. because it was found difficult to delimit; ’big questions often become very difficult to manage’, and that issues also change over time. In terms of strategies for arranging Teaching and Learning Activities, several participants describes using external parties for introducing ethics, in e.g. workshops and seminar discussions.

Ethical issues also in many cases came into more general projects; ’we run project based education which means they need to relate to the situation in which you act’. In some cases the ambition seems to be to set a good example; ’Throughout the years, none of our students have worked with or considered working with arms related projects’. Another participant brings up projects that could be problematic; ’I encourage the students not to just say no to things that could be questioned but where you could possibly make a difference’. Problematizing is in some cases also made intentionally; ’We run projects with things that provoke a bit- critical design and things like that’. Some even use the provocation as an explicit teaching strategy: ’We work with project that have an ethical anchoring, but also projects that are purely provocative- To see if they react to it’.

Our respondents claimed to have explicit learning objectives concerning ethics, but they did not seem to be driving how ethics was taught. Similarly, our participants were of the opinion that ethics was brought up not so much in a distinct teaching and learning activity, but throughout their educational programs; ’…give room for reflections, not just one truth and politically correct projects. /…/ It says in the curriculum that it should be part of. But it is probably more like an ingredient that should be part of the totality”. In terms of specific Intended Learning Outcomes our participants quoted general descriptions about e.g. sustainability. However, it seems like Intended Learning Outcomes were not always formalized, but in some cases remained a tacit expectation based on norms. However: ‘We need to be careful about planting too many values. You can end up brainwashing people’, or as put by another participant ’There are some problems with taking one ideal or another as a starting point for teaching. Who’s ideal is it that should be followed?’

While several participants comment on ethics as being central to the profession and to many projects; they seemed less confident that it is explicitly addressed in assessment; ’(We assess) novelty of ideas, how well the product is adapted- and through that also the ethical I suppose’. Another participant put it ’We don’t address ethical questions directly but we expect students to present in a way that shows awareness in relation to questions and norms’.

2.4 Insights

Not surprisingly, the interviews indicate that students may need support in engaging with ethics, but ethics as such did not appear to be at the core of teacher’s competence. While participants also brought up some alternatives, the dominant teaching strategy seemed to be based around discussions in relation to projects based on more or less tacit norms. Nevertheless there seem to be some keys in relation to teaching ethics. More particularly: students could be provided with situations triggering reflections, opportunities to see nuances of issues, being able to see and respect the positions of others (e.g. users), and understanding bases for these positions. Themes for assignments could also be selected as to be more or less engaging / provocative to students.

3 THE WORKSHOP

The authors hosted a small workshop with postgraduate students, lasting 3 hours. In this we strived to incorporate some of the insights from the interviews. The onset was to through as series of moves (see table 2) trigger reflections, engage the students in elaborating issues, and to convey some basic alternative foundations for moral reasoning (see table 1). Furthermore it was considered important to draw on examples of relevance to participants. The ambition for the workshop was to find themes that were of significance to participants, take them one step further in explicating their own positions, make them aware to realize other positions, and consider alternative grounds for making priorities.

Table 2. Moves in the workshop

Workshop phase	Activity
Preparations	Students reflect on answers to preparatory questions about examples relating to their practice where they have a) taken a position b) find challenging
Explicating issues	Students describe their problems and explain their positions to peers
Presentation	Teacher give short lecture covering examples and a conceptual framework stressing dilemmas
Identifying dilemmas	Students actively employ a model in elaborating dilemmas in 'their' problems
Feedback & Discussion	Teacher gives feedback, discussions in group
Presentation	Teacher give short presentation of alternative principles for making ethical judgements
Considering alternative positions	Students actively experiment with alternative ways of looking at their dilemmas.
Feedback & Discussion	Teacher gives feedback, discussions in group

Regarding the content of ethical challenges, students brought up issues around e.g. Nuclear power, Inequality between 1st and 3rd world, and gender issues with toys. Commenting outcomes and benefits from insights one student emphasized being able to see inconsistencies in own positions but also seeing that there are alternatives and possibly thereby respecting others results in having different choices. Other students agreed; 'Like you said: I thought I had a clear opinion but now to understand myself better'. In this, we also had some positive comments in relation to introducing theories/conceptual frameworks; "the frameworks helps you take a stance. For me it was very easy to come up with answers to the three questions, but it was really interesting to expand with the different perspectives. However, students also pointed out that universal principles can be difficult to access without concrete practice; 'I think it helped to have a test and try the theories. Have taken course where most of the theories were applied but having a tangible exercise wand listening to the other examples really helps.'

4 DISCUSSION

The following section categorizes findings within the aforementioned three dimensions of ethics in design:

Ontologically, Both in design literature and amongst educators there seem to be a conviction that design is steeped in ethical issues, with a dominant theme being that designers need to understand the position of others.

Epistemologically / methodologically, there seem to be reliance on tacit reasoning; on established professional norms and intuitive moral reasoning. However, some educators also show a concern for situations were students are to mimic a value-system, calling for more informed approaches. Our workshop also showed that it is possible to make students realise that different positions can be taken, and that it is possible to give them complex conceptual tools and methods also within quite a limited period of time.

Practically, designers face a range of value laden decisions, both in relation to concrete design tasks and in relation to deciding whether to take on a certain project or not. It may be that some industries are easily avoided, while a person can also chose to take on the challenge of engaging with a project with transformative aspirations. Relating to ethics in design education the practical level can be used to reflect upon students' own design decisions related to products and services, but also how the communicate with stakeholders. It is also important to make students aware that they can make a point for their decisions in projects but are not alone responsible for the chosen solution. Finally educators should consider if a particular case requires ethics since not all design practice require ethical reflections.

5 CONCLUDING REMARKS

This paper is to be seen as an initial attempt at approaching value-laden questions in design from the perspective of ethics. The interviews were held with limited number of informants, sharing their reflections on how ethics is taught. A more formal analysis based on a more extensive theoretical and empirical material, would be desirable, and we are grateful for suggestions as well as critique as we are planning to extend the study. Conclusively, ethics remains central to the design professions, and given the professional needs we expect it to be necessary for teachers and students to acquire skills in ethical decision-making in the future. Actively supporting students in comprehensive reflections beyond surface level acceptance of doing good, poses an important challenge to HE design programs. Conceptual tools, frameworks and theories, can at least to some degree support such reflections. For the future it remains to clarify and expand the ethical considerations/criteria for the development of product solutions and to implement them systematically in the overall product development decision-making and its trade-offs.

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SLOW FASHION IN THE SPORTS APPAREL INDUSTRY

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ABSTRACT
Overconsumption of natural resources is a vicious circle as we harvest more from nature than it can replace at its natural pace. This overconsumption is a result of the consumer society's insatiable need for new products, which, in turn, has a number of negative effects on the environment and society. This paper addresses the designer's responsibility to find sustainable solutions, as approximately 80% of the environmental impact of products is determined during the design phase. One method used to reduce consumption is the theory of slow fashion. Few studies have been done on this subject related to the sports industry. The research question is, therefore, as follows: How can the theory of slow fashion influence designers to make sports apparel more sustainable? The methods used were three case studies and an in-depth interview. The case studies were carried out in three different contexts. These were the companies Patagonia, Inc., Norrøna AS and Plusminusnoll Outdoor AB. The results of this research show that applying this theory in all three companies could potentially improve their products. This paper can contribute to a better understanding of slow fashion and inspire designers, businesses and consumers to lessen their consumption and improve social conditions.

Keywords: Slow fashion, sports apparel, the designer's role, social and environmental sustainability

1 OVERUSE OF RESOURCES

This paper discusses what a responsible economy can be. Economic growth is often the strongest driving force in companies. By moving their production to low-cost countries, they thereby increase the pressure on human and natural resources, their products are sold more cheaply and they contribute to increased consumption in Western countries [1]. According the *Living Planet Report 2014*, we are using resources equivalent to one and a half globe [2]. This means that we are using resources that take longer than a year to regenerate. The same report shows that if we continue at our current pace, our consumption will be equal to three planets in 2050. From these figures, the need to take action against this overuse is clear. However, this is a complex task, and this paper addresses only a small part of the problem, concentrating on sports apparel. The sport apparel industry has major challenges concerning sustainability because the use of harmful chemicals and high consumption of energy and water in the production process [3]. Some companies takes this more seriously than others, in terms of material selection, free mending of used garments and recycling.

2 BACKGROUND: SPORTSWEAR SALES

Sales of sports apparel show a rising curve, and, according to a global market survey by Lucintel, this growth will reach a value of 125 billion dollars in 2017 [4]. This also applies to Norway, where sales have seen a large increase over the last 20 years [5]. Companies usually focus on rapid production and increased sales. Economic growth has long been their driving force and, thus, has laid the foundation for a social and environmental exploitation of labour and materials in a market that demands more and more [6]. Trends change rapidly and create insatiable needs for many people [1]. This has resulted in many cheap products of poor quality, as consumers in many cases replace their apparel regularly. This phenomenon is called 'fast fashion', which has major negative effects on the environment [1]. A counter reaction to this is 'slow fashion', which takes its inspiration from the 'slow food movement' [3].

Slow fashion is about raising awareness about production, working conditions, communities and ecosystems [1]. This ensures a healthy rhythm between natural resources, production and consumption. Slow fashion is a complex theory introduced by Flatcher in 2007 [7]. The difference between fast and slow fashion is not just about speed. They represent different worldviews where business models, values and processes have fundamental differences [8]. Previous research on the slow fashion theory by Jung and Jin found five factors in slow fashion [3]. These are equity, authenticity, functionality, localism and exclusivity. Equity involves working conditions, fair trade and living wages. The cited authors defined authenticity as tailored products, small-scale production and preservation of traditional handcraft techniques. Their definition of function addresses durability, timeless design and multifunctional use. Further, they propose the factor of local production to create valuable associations, using local labour and materials. They defined the last factor of exclusivity as rare or unique products that can be used to build identities. In the research discussed in this paper, these five factors of slow fashion were examined in three different manufacturers of sports apparel. This was done to investigate whether slow fashion theory, or elements of it, is used by these firms in their social and environmental operations. Similar research was not found in a literature search. The research question is, therefore, as follows: How can the theory of slow fashion influence designers to make sports apparel more sustainable? The hypothesis is based on an assertion from Jung and Jin's article, that the business model of slow fashion is only suitable for small and medium-sized businesses [3].

3 METHODS: CASE STUDY AND IN-DEPTH INTERVIEW

The methods used to address the research question were a case study method and an in-depth interview [9, 10]. The purpose of this was to understand if the three different manufacturers of sports clothing are applying the theory of slow fashion. Case study was chosen as a method to build an understanding of the theory and investigate whether it is relevant to these three companies [9]. The topic was investigated in three contexts in order to test if the theory can be used in various business models. These contexts were Patagonia Inc., Norrøna AS. and Plusminusnoll Outdoor AB. These are, respectively, representative of large, medium and small businesses. An in-depth interview with industrial designer Kjersti Kviseth was conducted to gain a deeper understanding of the theory and to get her views on the sports apparel industry. She has 10 years of experience as a former environmental manager for the office chair manufacturer HÅG, and she is an expert on textiles and sustainability. The data collection in the case study was done through document analysis of websites, lectures, articles and earlier interviews – to understand the past and current practice of the companies [9]. The embedded units in the cases were the five factors in slow fashion, based on previous research [6]. These were analysed by using pattern matching. This examined to what extent the embedded units were coincident with the various contexts and considered whether these companies' approaches need to be revised based on the document analysis's findings [9].

4 RESULTS

This section presents the findings on the different factors of slow fashion in relation to the three different contexts. The factors analysed were equity, authenticity, functionality, localism and exclusivity.

4.1 Case Study 1: Patagonia

The context of the first case study was Patagonia. 'What is a responsible economy? It's one that cultivates healthy communities, to create meaningful work, and takes from the earth only what it can replenish. It's one where all the indicators are currently going in the wrong direction' [11]. This quotation was taken from Patagonia's website, which shows that it wants to take responsibility and that the company acknowledges the problems related to the industry in which it operates. Patagonia appears extremely quality conscious. It sets strict requirements for materials, as they must be durable and have functional features to fit the users' needs [11]. The company encourages customers to buy less by partnering with eBay to sell used clothing [12] and by communicating messages through billboard slogans such as 'Don't buy this jacket', where they encouraged customers to repair their old jacket instead of buying a new one (see Figure 1) [13]. It also has the largest repair service in the United States [14]. Further, on its websites, Patagonia.com reveals that it is actively working to improve the daily lives of its factory employees [11]. It shows transparency in details of its challenges and previous mistakes. It does this by engaging independent third parties to verify quality in their textile mills and sewing factories [15]. The company admits that providing living wages at its factories is a major challenge, with which it has a long way to go. In this study, Patagonia emerged as honest

and passionate, with a huge commitment to corporate social responsibility (CSR). Through 'The Footprint Chronicles', it shows the story behind each product it sells and, thereby, gives consumers an opportunity to make conscious choices [11]. Patagonia has eight factories in the United States, but stresses that it is not a 'Made in America Brand'. The company states, however, that it believes in long-term environmental benefits by producing locally but that this possibility is prevented by two short-term factors. These are the extensive measures necessary to change company logistics, and the statistic that only 2% of carbon emissions occur during transportation from factory to store [11]. Patagonia showed in these results that it has many good initiatives and can serve as a good example for other businesses. However, it is still far from perfect. The following quote from the company's owner and founder, Yvon Chouinard, confirms this.
'Patagonia will never be completely socially responsible. It will never make a totally sustainable non-damaging product. But it is committed to trying' [12].

Figure 1. Patagonia advertisement from the Friday, 25 November, 2011 edition of The New York Times

Patagonia did not satisfy all the embedded units of slow fashion, but they matched the function factor quite well. It also showed many good measures in relation to equity as compared to many other businesses their size [15]. However, only a small percentage of their products are locally produced. Authenticity and exclusivity were also untouched.

4.2 Case study 2: Norrøna

The context for the second case study was Norrøna. In a videoconference from The Norwegian Centre for Design and Architecture, Norrøna's chief executive officer, Jørgen Jørgensen, stated that quality is the entire company's foundation [15]. Jørgensen also argued that family businesses, such as Norrøna, often make decisions based on a long-term perspective, as they have traditions and visions for the future of a more personal nature. Norrøna has repaired products for over 85 years, and it encourages customers to take care of its products. The embedded units of function, therefore, fit Norrøna well. Regarding local production, it responded by mail that the company used to produce items in Europe but moved production to Asia as the volume and time pressures increased. They also justified this by stating that they did not get the quality they wanted in Europe. The majority of its production is now in China. Norrøna only gives away supplier lists upon request. In Norway, only two of the 10 largest suppliers of sports apparel operate with open supplier lists [16]. Compared with Patagonia's 'Footprint Chronicles' Norrøna has potential for improvement in this area. It admitted further that it is not as good in CSR as Patagonia, since Norrøna, among other major challenges, struggles with overtime [15]. It is now working actively to prevent this by smoothing out production throughout the year. It wants to prevent a build-up of pressure on workers before the winter and summer seasons by improved planning and information. It also has some products constantly in production to guarantee work for employees throughout the year. Norrøna can be perceived as internationally exclusive, with the Nordic ø in its name and the logo of Birkebeiner [17]. Norrøna matches the embedded unit of function and, to a certain extent, exclusivity. The company has potential to improve in equity and local production. The embedded unit of authenticity was not noted in its policies.

4.3 Case study 3: Plusminusnoll

The third case study's context was Plusminusnoll. It operates with small-scale production in the European Union (EU) [18]. Wages, working hours and conditions, therefore, are regulated by the EU, which gives the company an opportunity to control its production processes to ensure good quality products. Plusminusnoll has a different business model than what is customary in this industry. The company wants to focus on the product itself rather than just lower costs more effectively. Quality clothing with a focus on the end user is its goal [18]. It produces products only on a pre-order basis, as they do not want to contribute to impulse shopping and sales items. It takes six months before a customer gets the product because the company wants to stimulate people to plan their purchases based on actual needs. This model also leads to less time pressure in production. Plusminusnoll sells products directly to the customer and, thereby, cuts out expensive distributors. Since it does not have expenses related to warehouse spaces, it can spend more on quality materials, in addition to making cheaper products. Plusminusnoll's products, to some extent, can also appear exclusive, since they do not exist in large quantities. The fact that customers have to wait long before they get the products also makes them more exclusive. Based on these findings, clearly Plusminusnoll largely corresponds with most of the embedded units. It ensures good working conditions and, thereby, equity; it makes quality products and fulfils the criteria for function and it is exclusive. However, it does not make customised products or produce in Sweden, as the factors of localism and authenticity demanded.

5 DISCUSSION OF FINDINGS IN TERMS OF THE INTERVIEW

In the interview, Kjersti Kviseth confirmed that many examples exist of positive initiatives in the sports industry today [14]. She believes that no direct examples can be found of companies using slow fashion consciously but that Patagonia is doing this quite extensively. Kviseth points out that the factor of quality is actively used by many businesses. Factors such as tailored products are currently less relevant, but she thinks that these will become more common in the future, as she envisions new business models and ways to design for slow fashion. These views fit with the findings in the three company contexts, since all the companies had good values and practices around the factor of function, while none customised their products. The issue of local production has proven to be complex and difficult. Kjersti believes that this transformation could be easier for smaller companies, such as Norrøna and Plusminusnoll. This does not mean that larger firms such as Patagonia should not move production closer to their main offices, as she thinks it questionable what deeper insights and influence are possible with factories at large distances [1]. Kviseth confirmed this in the interview, and she think it is strange that Patagonia does not believe in local production. She added, however, that the production of sports garments requires high levels of competence and technology and that companies cannot just take over disused factories. She sees room for further discussion about whether local production can provide valuable associations for brands and warrant higher prices, which can be a major factor in the debate over what a responsible economy might be, showing how much a jacket actually should cost.

The case study showed that Patagonia is an important contributor in the sports apparel business, since they dare to ask many of the important questions about working conditions, consumerism and environmental effects. However, the company's policies do not match all the embedded units and, therefore, it cannot be used as a clear example of slow fashion [14]. Parallels can be found between Patagonia and Norrøna, as they both focus mainly on making good quality products that have the least possible environmental impact [15]. Nevertheless, the case study showed that Norrøna has some challenges in relation to equity, and it is failing to communicate as clearly its commitment to lower consumption as Patagonia is. Norrøna, therefore, has room for improvement in terms of the slow fashion theory. Plusminusnoll matches many of the embedded units quite well, and it is consequently the best example of slow fashion of these three firms.

5.1 Audit of the theory

Based on the case studies, function was clearly the most relevant factor in the various contexts studied. This factor is about a lasting and versatile use of products. In this context, the term might seem vague, as it often is associated with how well a product functions in practice and not with how durable a product when compared by service, repairs or timeless design. A new proposed designation of the term is 'longevity'. This term reflects the factor's full purpose and not only parts of it (see Figure 2 for an illustration of the new proposal).

Figure 2. Shows a visualisation of slow fashion in revised form

5.2 The designer's role

Kviseth underlined the importance of the designer's role, especially when the designer has the authority to take decisions [14]. She alleged further that teaching sustainability has been completely diluted in design education in Norway today [14]. This is a critical point since designers have great opportunities to contribute to a more sustainable society, when approximately 80% of products' environmental impacts are determined in the design process [19]. For this reason, teaching about these consequences is of fundamental importance in design education. Designers can work as an essential teammate in the process since they have an entire toolbox with them to contribute innovative ideas that can make a significant difference [14]. In the textile industry today, the process from sketch to finished product might only take three weeks. This often results in the manufacturers copying each other's designs, as this makes things go much faster. However, the result is often homogeneous products of poor quality [1]. This is also evident in sports clothing, as many products are quite similar to each other. By spending a longer time in each stage, designers can get a much greater opportunity to design distinctive identities and characteristics into products. This again gives the end users much greater choice, finding their true identity and increasing the chance that the product will be used for longer.

6 CONCLUSION

In this study, the theory of slow fashion was applied in three different contexts to examine how designers can make sports apparel more sustainable. This is a complex task, which was further studied with an in-depth interview to get a better understanding of the topic. Apart from this interview, this paper reports primarily on one designer's encounter with this complexity.

This study strengthens the hypothesis that slow fashion can be implemented more easily by small businesses. Whether or not larger companies could also benefit in adopting slow fashion is still open to debate, since Patagonia has successfully incorporated many of the theory's factors [15]. Based on this research, the results show that the manufacturers studied do not use slow fashion deliberately, but the concept may become more highly relevant in the future [6, 14]. This paper can contribute to improving the understanding of slow fashion and can serve as an inspiration to designers and companies who seek to contribute to their businesses' better social and environmental sustainability. The theory of slow fashion can influence designers to make more sustainable sports apparel by revealing the larger picture of nature and the world as a whole. All aspects are interconnected and influence each other. By considering all the factors in slow fashion when products are developed, designers can contribute to significant advantages for nature, companies, employees and end users. This is not an easy process – requiring new business models – but it is essential to answering today's challenges.

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WELL BEING AS A CRITERIA FOR PRODUCT DESIGN

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ABSTRACT
Historically, Product Designers have concerned themselves with manufactured objects through negotiated briefs for clients either as external consultants or in-house designers. Within this remit traditional attributes of a product are well understood but the defining criteria for success is the bottom line of profitability. However there has recently been a shift in application of the design process to a diverse range of market sectors and problems. With this comes a reappraisal of the criteria which designers should use to gauge success. Product Designers should acknowledge that they have a responsibility, beyond the bottom line of usability and commercial profit, to deliver equitable value to many stakeholders. Among these values are social indicators such as well-being in contrast to short term desire (point of purchase), happiness or pleasure rather than functionality and value for money. The values by which design outputs are judged have become increasing more complex. This paper sets out to explore these issues and a call for Product Design application to expand from purely commercial to that of responding to human requirements whether individual, communal or cultural. It attempts to address what we mean by the terms well-being and happiness and how these can form part of both a design brief and a mechanism for judging success. It uses a series of student projects as case studies to introduce these concerns to design students and finally muses on the value of design itself as a mechanism for creating positive sustainable futures.

Keywords: Well-being, happiness, pleasure, word-circles, design research, design methodology,

1 INTRODUCTION

Research has indicated that Happiness in the Western World Peaked in the late 1950's. This correlates with the accelerated growth in both Product Design and Consumption [1].

Product Design (PD) including education is at a pivotal point in its evolution. That is the first phase of understanding industrial design, the attributes of the manufactured product are well understood, and the educational programmes structured to equip students with the necessary skills and understanding to work within the discipline are well established. However the attributes of design have, by necessity, been focused towards functionality, appeal and profitability as it has predominantly been funded by manufacturing industry. Both of these are short-term attributes which have inevitably been linked to increased consumption. Tim Jackson observes:

'Why is it that material commodities continue to be so important to us, long past the point at which material needs are met, Are we really natural born shoppers?' [2]

He continues:

'What is it about consumer goods that continues to entrance us beyond the point of usefulness?'[3]

If we now include the current concerns of ecological and social sustainability into this equation we have a conundrum: on one hand PD has achieved its initial aim, better products, but new issues relating to the bigger picture of attaining a sustainable future have been wilfully neglected. It is time for PD to re-consider what its' true purpose and value is. Part of this re-evaluation must include the stakeholders affected by design and the actors who can directly influence design decisions.

'Here an actor is defined by a person or organization that will remain centre stage and is essential to the main storyline of the design project. A stakeholder is any person or organisation that will have an effect on and/or be affected by the design project' [4]

Here we meet a new question in that if we are going to expand the application of design to meet a more complex range of requirements then we need to consider new criteria by which we initiate design responses as well as validate and assess our designs. This shift of emphasis has already started both in theory [5], [6] and in practice by design groups such as Massive Change, Project H and Shift Design.

Much has been written about the need for sustainability and change. The initial driver for this was a growing awareness of the damage that human activity is doing to the planet. Within these debates the concept of three systems, ecological, economic and cultural (or social) has become accepted as platforms on which we need to create a balance to maintain a sustainable future. Whereas ecological damage(s): Resource Depletion, Climate Change and Human Health [7] are well understood even measureable, what we mean by Cultural or Social needs becomes more open to different interpretations. One key observation is that the changes necessary to create a balance between human activity and ecological sustainability may be instigated through behaviour change or new paradigms within the Cultural System of Sustainability [8], [9]. To fully understand the consequences of change and how to 'design' a sustainable future we need to further unpick what we mean by Cultural or Social Sustainability and ultimately map this onto the design process. In this way we can consider how we train designers to operate within a new framework. What will be the Cultural or Social Drivers for Design? By what metrics will we measure success?

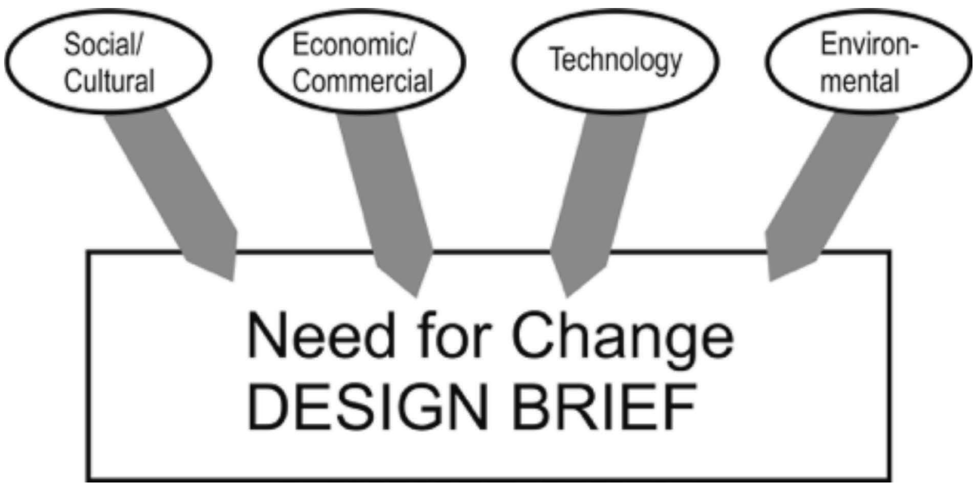

Figure 1. Drivers for Design

This paper explores, through student projects, how PD education can adapt to make the next generation of designer aware of new roles for design and reappraise associated value systems. It aims to unpick some of the complex issues. It is a work in progress raising more questions than it answers.

Within the above understanding is the notion that a need within a social or cultural construct is both a logical and aspirational driver for design. But some of the characteristics of social design are about the human condition and we use terms such as happiness, joy, harmony [10], [11]. These are difficult attributes to quantify. As Robert F Kennedy stated.

The Gross National Product does not include the beauty of our poetry or the intelligence of our public debate. It measures neither our wit nor our courage, neither wisdom nor our learning, neither our compassion nor our devotion. It measures everything, in short, except that which makes life worthwhile. [12]

If these attributes are to become criteria for design we need to explore how we can validate designs against these values from initial problem/issue identification to criteria for success. However we first need to understand what we mean by these terms.

2 RE-STRUCTURING DESIGN EDUCATION

PD is in a strong position to expand its remit as it is now constructed on a strong understanding of the design process or methodology for instance, Design Council Double Diamond [13], Service Design Thinking [14]. This acknowledgement of the value of the design process (or design thinking) is taught in several Universities [15]. The projects below report on initial work to raise awareness of social

issues within student designers while exploring terminology associated with social or cultural constructs. An important aspect is how the research is narrated/presented and connected through each stage of the design process. These case studies are examples of approaches not completed projects. The aim is a shift in perception amongst students to questions PD beyond traditional limitations. The project (or sub-projects) outlined below were all conducted with second year students. During the first year they learn all the traditional skills of a product designer and the second year initially concentrates on the purpose of design and how research informs this building an understanding of the design process. In the final year students take greater responsibility for their own directions which can include social aspects of consumer needs.
The case studies indicate methods of approach rather than complete projects. The example at the end demonstrates how an understanding of social issues have influenced a design proposal. All the tasks were supported by lectures on the context of social/cultural sustainability.

3 INITIAL EXERCISES

3.1 Mapping Relationships: Possessions and People

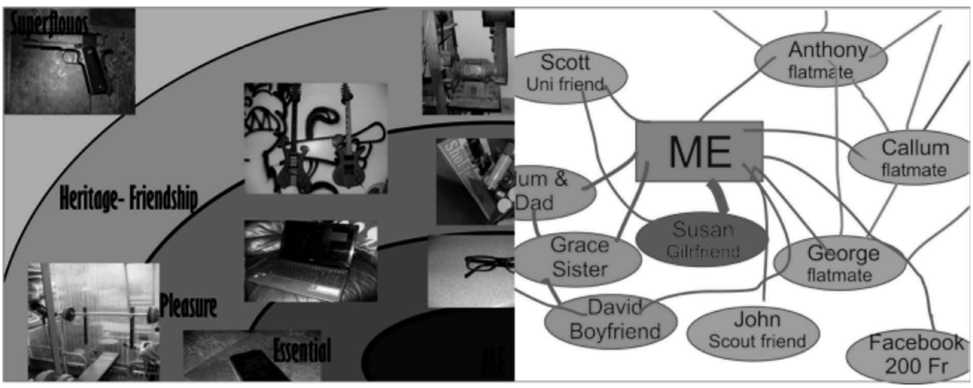

Figure 2. Mapping Possessions and Social Relationships

Within these exercises students have to visually map their own possessions and relationships. With possessions there is a hierarchy of need from essential through self -esteem to superfluous. The context is to make students aware of the values by which we engage with products. The second exercise is to map relationships within a social environment, a family house or shared flat. Starting with themselves they map out relationships to others and reflect on why these relationships exist. With both exercises it is important that the work is presented visually at a large scale to foster engagement and discussion.

3.2 Exploring Terminology: Word Circles

Initially design was placed in context of social sustainability (individual and community) through a lecture and open discussion on how design can have a positive impact. The final part of the session was to explore in 'words' what we mean by Well Being and Happiness. Students were asked to consider words which define these two terms. These 'words' were then written on a white board to form two 'word circles'. Each student was then asked to draw a line between the two words (In the circle) which they felt were most important to the term. By this method key words became apparent due to the number of lines originating from them. In the example in Fig. 3 the word Freedom becomes important in facilitating Happiness.
By this democratic method the group became aware of what constitutes Well Being and Happiness (sometimes substituted for Pleasure within the exercise). From this simple exercise the notion of using these words to validate design choices was introduced. The next step was to introduce Project Briefs which incorporated this shift in thinking to exploring emotional or human responses and reactions.

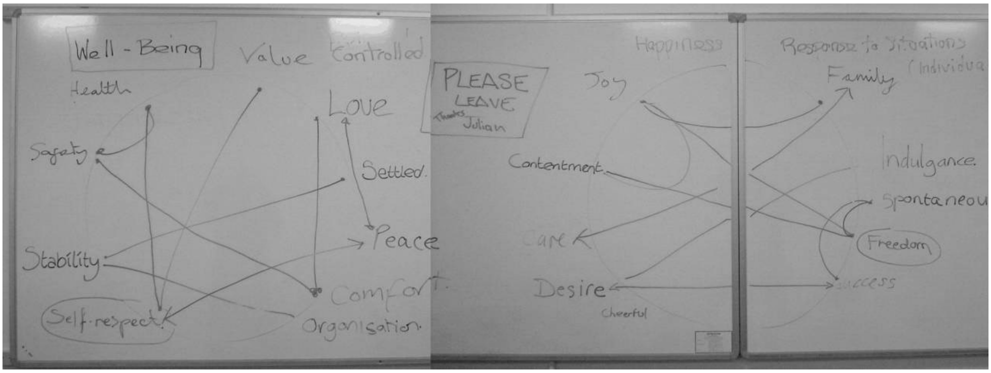

Figure 3. Well Being & Pleasure Word Circles 2010

3.3 Task Analysis 1: Emotional Response

Figure 4. Scenario & Pleasure Time Line

Initially the brief appeared a simple redesign of a functional product. However the approach was analysing actions. As an example, making a hot drink from the point when the drink is required to the consumption of it, rather than just analysing a kettle. By these means the students were encouraged to get back to first hand research rather than rely on assumptions. It also opened the possibilities of innovation (a new way of seeing) rather than incremental change of an existing product. This task was achieved through a series of photographs plotting the scenario. Students had to analyse and annotate these storyboards. In conjunction with this exercise and presented alongside the scenarios, students had to plot a timeline recording pleasant and unpleasant experiences within the storyline photographs (Fig. 4). To further emphasise the analysis of need rather than assumption, students, as part of the exercise, had two further diagrams to consider.

3.4 Task Analysis 2: Scenario – Activity – Incident

The Scenario-Activity-Incident (Fig. 5) created a hierarchy of events in a situation either using a product or undergoing a process. This prompted students to consider where design interventions could have an effect, also whether these would be at incident level, for instance improving ergonomics, or within the scenario finding a different way to accomplish the need. This approach is a derivative of Empathic Design Tool 10, Empathic Design Tutor.

'These individual needs are normally directly related to specific product interactions or parts of activities. Here it is important to visually represent the relationship between individual needs, & between needs, incidents & activities.' [16]

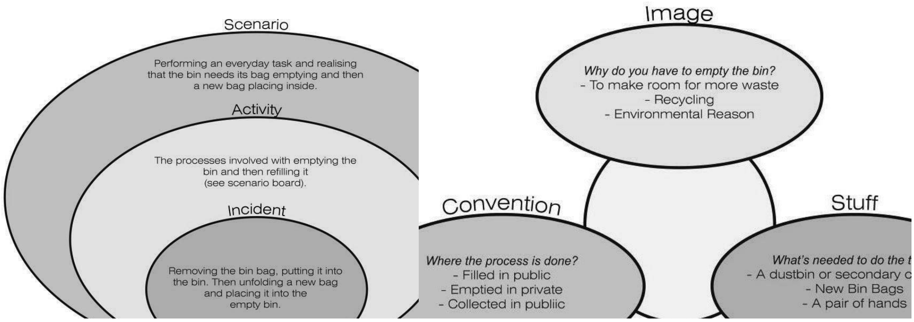

Figure 5. Incident-Action-Scenario Diagram & Stuff-Heritage-Ritual Diagram

3.5 Rituals: Stuff – Image - Convention

The second diagram to populate, (Fig. 5) after research at TU Delft University, gets students to think about ritual and cultural/personal perceptions. It asked them to consider stuff needed within the activity as well as conventions associated with the activity and the image or perception of undertaking the activity.

The final design brief was simple: take an unpleasant experience from the research and through design intervention create a pleasurable activity. The objective of the project was to get students to respond to issues in new ways while generating a different set of criteria to guide and validate their decisions, in this instance pleasure and happiness. That is identification of need from an emotional rather than functional analysis.

3.6 Rituals: Functional and Psychological Needs

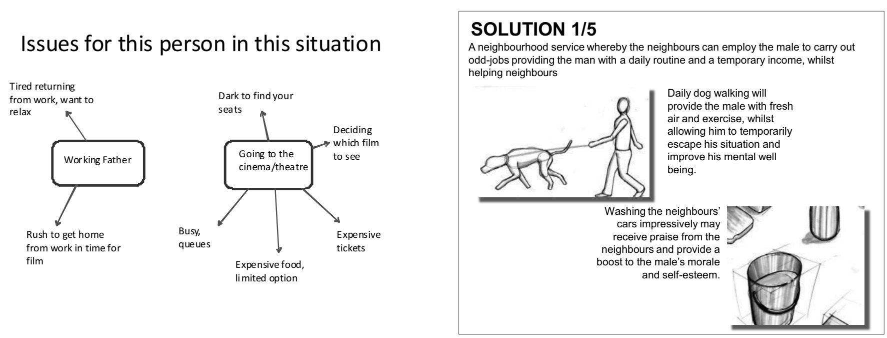

Figure 6a. Mapping emotional needs & b. Social Response

This exercise moved from need to scenarios where an individual was put into a social context or scenario. Profiles, such as 'Working Father (single parent), and contexts including 'Going to Theatre/Cinema' were selected randomly Fig. 6a. Students then had to analyse these contexts from the users perspective, as a spider diagram exercises. This broader approach allowed students to research all issues connected with individual or social needs.

4 RESPONSES

The projects continued to a design proposition stage and were critiqued against the initial word circles. Fig. 6b is an example of a social service whereby an unemployed man can regain self-esteem by becoming of value to a community. This improves personal and social well-being.

5 REFLECTION AND FURTHER WORK

The above exercises are set to broaden students understanding of product design from purely the physical object to a wider understanding of need. The term 'improving well-being' can loosely be used as an underlying objective of these projects. An important learning curve is a re-evaluation of the terminology we use [17]. For instance shifting from 'product to need' and 'ownership to experience' facilitates new and appropriate responses from designers. In essence the authors are aiming to instil a sense of new values within the student experience supported by the necessary processes to explore, express and respond to new social or cultural demands. As the terminology used is subjective, it is important that we equip students to articulate both verbally and visually meanings and contexts for their work which are effective within existing Design Methodologies. This is very much a 'work in progress' The next step is to forge better links between the terminology used in defining problems and the criteria used to evaluate success of a project outcome. Importantly, the exercises outlined above get students thinking, debating and reflecting on social issues. They form a good platform of understanding prior to the final year of study. The key Learning Outcomes of these Projects are:

1. That social criteria can drive and validate design decisions.
2. The value of exploring categorising and communicating social issues.
3. Exploring processes which facilitate and communicate the above.
4. Linking social need to design solution.

Alastair Fuad-Luke sums up this opportunity

'If sustainability is the most challenging wicked problem of the current era, then participation in design, as a means to effect deep, transformative, socio-political change, seems essential. This suggests a significant new direction for design to seize'. [18]

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USER INVOLVEMENT IN DESIGN OF HEALTH CARE SERVICES

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ABSTRACT
During the last decade, industrial designers have entered the arena for design of health care services in cooperation with health professionals. Parallel to this, user involvement has been recognised as an important part of quality improvement work in health care, acknowledging that users have their own type of expertise. This has resulted in an increased focus on involvement of users in both evaluation and design of new services. User involvement is an important aspect in both a health care and a human-centred design context. However, neither of the fields have "one good reason" nor do they have "one best way" to do it. This article explores and compares user involvement in the two fields.

Keywords: Health care design, service design, health technology, user involvement, consumer involvement, design for welfare, patient involvement, user-centred design.

1 INTRODUCTION

There are several factors calling for changes in health care services. Global shifts in population demographics make people question how it is possible to deliver health care services of good quality within the national budgets. The views on health and what defines good quality of health care are changing from disease-oriented models to more holistic approaches focusing on factors that support human wellbeing[1]. At the same time politicians world-wide want to increase the user-friendliness of the health care services and give the users a voice in the development process [2]. Design thinking and "designerly" ways of working have been announced as approaches that could find new and creative solutions in health care [3, 4]. This has resulted in an increasing number of designers participating in projects in the health care context. Designers and health care professionals share a focus on the users, but the views on users and how they should be involved differ considerably. But for effective multidisciplinary cooperation it is important to have a common understanding of central concepts, like who are the users, how should they be involved in the process, and are there other equally important stakeholders. This article seeks to answer these questions based on a literature review in two different fields, human-centred design and health care.

2 USER INVOLVEMENT IN A HUMAN-CENTRED DESIGN CONTEXT

User involvement is often used synonymously with terms like: "focus on users", "consulting end-users", "contacting with system" and "participation of users" [5]. It is not a question of involving users or not, the focus in literature seems to be on understanding when and how the users have a place in the process, and which role the designer should take[6]. In a design context, the term "user" would commonly refer to people using a product or a service [1, 6]. In the case of health care services this might refer to patients, as well as carers, relatives, and health professionals. In order to differentiate between types of users, one often refers to primary, secondary and tertiary users. Primary users are the ones hands-on with the products or services. Secondary users use the product/service through a mediator. Tertiary users are people affected by the product/services and who might influence the purchase [6]. In business inspired approaches, users may be classified as lead users and end users. Similarly customer and consumer refer to users as purchasers of the products/services or at least the ones choosing between alternatives.

2.1 Why user involvement in a human-centred design context?

A simplified overview over user involvement in a human-centred design context is given in Figure 1. highlighting critical questions in different phases of a design process. Most designers do involve users to some extent [6], especially in the early stages of the process. Though it is debated to which degree processes with user involvement could lead to disruptive innovations as opposed to incremental innovations [11], research also indicates that users need to be far more involved in cases of high task or system complexity [7]. Verganti [10] proposes that designers should only know the existing context and solutions to a limited extent in order to be truly creative and create something new. Users do not necessarily know their own need or would know how to create something new and visionary. This is often referred to as design without users.

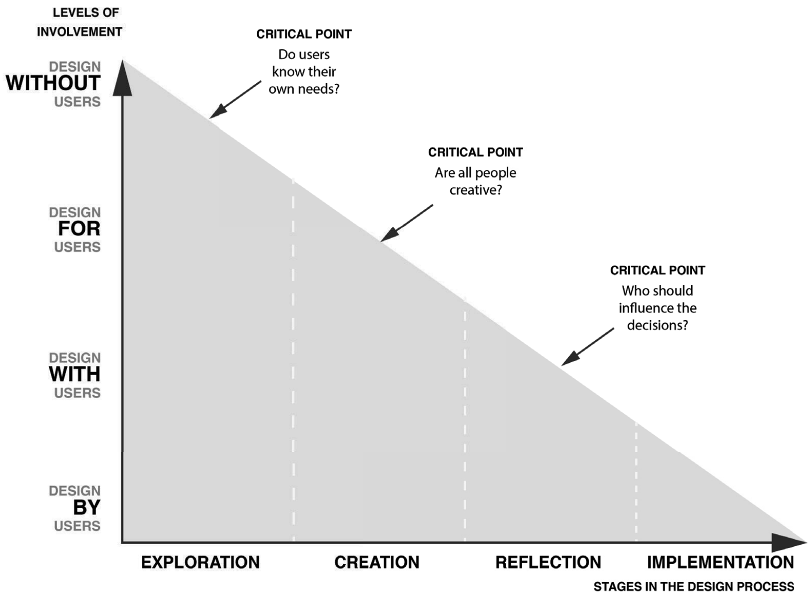

Figure 1. Simplified illustration of user involvement in a human-centred design process.

User-centred design approaches aim to make useful and usable products [7], and in order to do so they have an early focus in their process on users and tasks. The intended users are observed both in their real settings, confronted with prototypes, and to some extent interviewed by the designers. This could be seen as design for users. Designers differ in their view on whether people that are non-designers could be creative [6,8], and to which extent they could envision and create new solutions. As well as some believe that non-designers cannot envision future alternatives and solutions, others see everyone as creative. Approaches that see non-designers as creative would often invite users and stakeholders into the design process. This could be seen as design with users. To some extent it might even be the users that eventually design the product, resulting in design by users. One approach that embraces all people as creative is participatory design. "All people are creative, but not all people become designers"[8]

Co-design involves methods where different type of users and stakeholders can cooperate creatively and explore new opportunities [6]. Users are treated as experts with their own experiential knowledge and thereby an important asset in the design process [8]. The designers would support the user by providing tools for ideation and expression. The designer would still play a critical role in giving form to the ideas. Some take the co-creation process even further and suggest making toolkits that make lay people able to develop, modify and customize their own products [12]. Even though user involvement is considered to be somehow costly initially in a project, there are several economic benefits seen in these kinds of projects [5]. Further on it has shown to decrease training costs as well as the need of user support in the implementation stages. When designing services it is thought to ease the change process if the new solutions are proper anchored in the culture and organization [13]. The communication between developers and users may be challenging some times, and in some cases users has begun to request that changes be made to the system after being involved in development projects.

2.2 How is user involvement practiced today in a human-centred design context?

A design process typically starts with exploration of existing solutions and context. In order to understand users implicit and non-verbal needs field studies could be effective [8]. Some are concerned that designers will get prejudiced about user need when involving them to frequently [9], and that paying too much attention to the user may erode designer abilities to envision creative solutions [14]. A central question in this stage is to balance the individuals experience to what is relevant for all people, as well as balancing need of existing users with future users. Polaine et al emphasize the importance of using qualitative methods, together with quantitative methods. Qualitative methods often zoom in on a few individuals, while the quantitative methods may give you a better overall picture [15].

The next step is to create possible solutions based on the insight from the exploration. In order to reflect around the new solutions it is possible to test and prototype them. A central concern is to envision these solutions in a realistic and future context. Physical products can be tested by users with prototypes, but prototyping services is more complicated. When it comes to decisions, power is exercised and some actors have more agency in the decision-making process than others [6]. Implementation of new solutions is not the stage with most focus in design literature. When the new design is a service this could imply both changes in organizations and in technology [13]. Involving users earlier in the process, as well as using the insight when creating new solutions it is believed to give higher acceptance [13].

3 USER INVOLVEMENT IN A HEALTH CARE CONTEXT

The importance of user involvement in health care services is widely recognized. This applies to all levels: from the individuals own right to influence the treatment or care they receive, to the development of policies on national and global levels [16]. The methods used and reasons to for user involvement are diverse [19]. Most western governments emphasize the involvement of service users in their policies, but there seems to be a gap between these expectations and the work which is carried out on a service level [4, 18]. This might be due to lack of research on impact and actual outcomes of user involvement [18]. As Arnstein, put it more than 30 years ago: " The idea of citizen participation is a little like eating spinach: no one is against it in principle because it is good for you. " [19]

The users of health care services are named by a range of labels according to the context [17]. Generally "user" refers to persons on the receiving end of health care services. In literature their labels are linked to the underlying models and research frames [17]. Patient is widely used [20], as well as consumer and service user [16]. This article will refer to all these groups as "user".

3.1 Why user involvement in design of health care services?

Involving users is believed to increase the quality of care and lower the cost[20]. Give more accessible services through simplifying appointment procedures, extending opening hours, improving transport to treatment units and improving access for people with disabilities [20].

The two main approaches to user involvement in health care services are termed the "democratic" and the "consumerist" model [21]. Internationally consumerism is a model that is getting widely recognized in health care. The central idea is that everyone knows what is best for him or her, and when provided with choices on which services to choose they would spend their resources on the best possible option. The consumerist model is closely connected to "patient-choices" which encourages welfare states to let the users themselves choose between treatment options and thereby making the users consumers. The users do not always want these choices, and the critics point out that health systems are based on needs not on wants [22], but these arguments and beliefs seemed to be central in legislations world-wide. The democratic model sees user involvement as a democratic and ethical right. The health services are for the public, and as their users you have the right and duty to participate [23].

The last decade user involvement has been recognized as a central part of quality improvement work [4]. This is based on the belief that health care users are in a possession of an experiential knowledge that is essential for understanding and improving quality of health services. This knowledge is something you possess after a direct and personal experience with the services [17]. Research also shows that health professionals and service users differ in their view on what are the most important indicators for good quality of care [16]. In order to enhance the quality of the services it is pointed out that user involvement should not be carried out as a separate activity, but should be linked together with the other quality and assuring systems [16]. User knowledge should not be considered a rival, but a part of the overall evidence system [17]. Incorporating the user view on good quality of care could be seen as a power shift from the health care professionals towards the patients, but the responsibility of choosing the right measures and solutions is still with the service providers. Involvements of users have also been thought to improve the actual health outcome, and thereby giving still another reason for user involvement.

3.2 How is user involvement practiced today in design of health care services?

WHO classifies measures to support user involvement into three categories: choice, voice and representation [23]. Choice is the individual's opportunity to choose between service providers and treatment options. Voice are measures that give groups and individuals the possibility to provide feedback and engage in redesigning services. Representation means user representatives in boards and committees.

Relating to Figure 1, user involvement in health care development is usually carried out in the first phase of a development process and with the aim of gaining insight in order to design for users in mind. Mainly by letting service developers get insight into user views by user satisfaction surveys. User satisfactions surveys have a long history in the health care context [16]. This tool makes it possible to get quantitative measurements on larger groups of users. It is however questioned what these surveys actually measure. [16]. Whether users are evaluating their own health outcome or the service provided, or whether they are reporting their services or rating them in a way and not all institutions have the adequate systems for coordinating survey data with their quality improvement work[4]. It is considered a common failure that there is an inability to use the findings to improve services [16].

Whilst user satisfaction surveys could be considered insight material for service developers, the level of involvement also increases, by including user representatives in projects and board meetings [20]. User representatives are users with experiences from the health care services themselves, and often with chronic or long-term conditions. Often the same persons represent users in more projects and boards and there are concerns whether they take over the health care professionals' worldview after a while [24]. Some places user representatives receive training in order to get a broader understanding of the services. There is little evidence that the inputs from the users are used in the actual decision-making, and they are usually asked questions about pre-existing agendas. It has been questioned whether user input only is used to legitimise decisions that would have been made without them [24]. It is also claimed that managers and health professionals are "drawing selectively and strategically on user views" arguing with their assumption that only some of the user views are relevant do to the questions around representativeness. Health conditions may make it difficult to be involved [16] and some users do not even want to be involved. Other times it is ethically questionable to involve users if they e.g. do not have much more time to live. There is still a gap between policy makers' expectations and the actual involvement that take place today. In order to close that gap there is a demand for new knowledge and culture to support user involvement and tools to use user experience in quality improvement work [4].

4 DISCUSSION

User involvement is an important aspect in both health care and human-centred design, but for effective cooperation reflections around the different views and reasons to practice it are important [5]. Neither of the fields have "one good reason" nor do they have "one best way" for user involvement. Whilst the user in a health care context usually refers to the person receiving care, whether named patient, client or consumer, the designers' user relates to a broader range of people. Designers seem to have a stronger tradition on a more active user role in their projects. Both in levels of involvement and in which stages the users are involved. This is especially true in approaches that embrace the user as not only an important expert in their fields and context, but recognize them as egalitarian partners in the creation process. However there are some interesting nuances that are visible when we look closer at which "users" that would normally take an active part in e.g. service design project [25].

In health care there is considered to be a lack of knowledge on how to bring user research into service development [3]. Designer's on the other hand emphasize on the creation and reflection stages in the process, areas that are not covered in health care literature. Designers do not agree whether the user can be the one having ideas on the future alternatives, or whether they could only be involved as a source of inspiration. This has a parallel in health care where there are different views on whether the user should be consulted, be considered partners or even the ones in charge in the service development process. As well as designers have to balance their own knowledge and ideas with the users' knowledge and ideas, health professionals have to balance their knowledge with their users' knowledge. Some of the main concerns of user involvement in practice are shared between the two fields. First of all it is a balance between understanding the broader perspective by listening to individual experiences, and secondly to ensure that insight from exploration could be used in development of new services. Thirdly is to decide which voice to listen to in decision-making, and fourthly the entire process depends on the willingness in the organization to accept and put-to-life the proposed changes.

The health care context is considered evidence demanding. You might question how tools as storytelling and sharing of individuals stories will be seen by health professionals already annoyed by users being too subjective [6]. In health care user involvement is not only a tool and a method of improving the quality of services, it is also a right by law, and governmental legislations are emphasizing a more active role of the user – here the patient. Would this have any impact on how we as designers should approach user involvement in a health care context? When designers enter the health care context with own approaches to user involvement it is helpful to them to understand the existing traditions and approaches that are in use today. This might even facilitate the reflectiveness around your own role as designer and which methods and tools to use, as Steen asks for [6].

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THE PURPOSE OF INDUSTRIAL DESIGN DEVELOPMENT – DILEMMA OF ETHICAL & SOCIAL ASPECTS OF DESIGN BACHELOR AND MASTER PROJECTS IN LATVIA

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ABSTRACT

Industrial production is highlighted as the main source of development and well-being for the people. It is expected that design both as a process and the result helps to generate profit but ethical and social impacts of design are not considered to be the priority of the global market. Nevertheless designers argue that design is human and ethical activity.

What drives product development in industrial production and emerging school projects? Can products, developed according to ethical and social aspects, compete in capitalism economy?

The paper analyses the purpose of creative industry's design and industrially produced product development in a small country (less than 2 million people) and identifies booming design product specialization during financial austerity. Acknowledged and successfully produced niche products in the market are compared with the product development concepts in design education since 2010.

Research defines, that ethical and social aspects, especially identity and belonging as transformation of traditions, wellness and health, are important to a creative industry's design specialization of a small economy rather than industrially produced products. Ethical and social issues are the ground of micro-design-enterprises; however it is not sufficient for their successful development.

Ethical and social aspects, included in the early stage design process, favour the shift of design paradigm under the pressure of the global capitalism economy.

Keywords: Design purpose and values, ethics, social capital.

1 INTRODUCTION

The Third Industrial revolution and production is highlighted as the main source of growth and well-being, including new product development [1] – to produce more with digitization and technologies, renewable resources [2] and recycle-reuse shortened product life cycle approaches. Product development justifies business, technological or social purpose and mainly has two meanings: to expand company's activities or to design form and function of the product [3]. The latter one as new product development empowers businesses by innovating new products or redesign. New and innovative products embody values of the companies' or designers. Industrial companies need to have range of product collections as diversification or expansion of the market positions.

Niche design products are offered by micro, creative industries companies. "By addressing a customer's need in a way that's never been done before, a company not only stands out but establishes a tie to a niche consumer base" [4]. Therefore niche design products address socio-ethical and environmental aspects and as microbusinesses sustain local economy and employment.

Designers argue that design is human and ethical activity. Also, design helps to generate profit [5] as product competitiveness and added value to the products, the only indicator to prove that is a turnover increase.

The paper analyses the purpose and values of industrially produced and creative industry's design product development compared to student designed products in a small country with population of less than 2 million. The paper proposes the following questions: is highlighting of ethical and social issues a prerogative of design education and creative industry's niche products? Do products, that are developed to fulfil social needs, favour the shift of design paradigm under the pressure of global capitalism?

1.1 Methodology

The study is based on structured interviews with industrial designers whose design products are internationally awarded in design competitions. Industrially produced design products are compared to the design of bachelor's and master's product design concepts based on the information provided by industrial designers. Information about design bachelors and masters diploma projects is debriefed by the author during students' supervision process in design research and theoretical study.

Industrially produced products, that have international design awards, and national or international recognition or patented design bachelor's and master's projects since 2010, have been chosen as cases of this study.

The paper analyses design product development purpose and values. Why and what were the idea and meaning of the product development? What values did designer want the product embody?

2 THE AIM AND VALUES OF THE INDUSTRIALLY PRODUCED AND INTERNATIONALLY AWARDED PRODUCTS

In the last decade Europe and the world had been affected by the financial, administrative and social crisis that grew into threats of national freedom and independence. After a very rapid growth Latvia was the country that was hit by crisis the worst in the years 2008-2010. The years throughout financial, economic and social crisis have proved that restricted opportunities both for people and businesses open innovativeness and creativity as massive development of new products, business forms and markets. According to the Latvia Registry of Enterprises in 2011 there was a 34% increase of newly registered companies after the last enormous decapitation of labour in 2010. [6] Among them 22% were limited-capital creative industry companies. In 2013 there were 8-10% creative industries enterprises in Latvia. Since 2008 design products and services designed in Latvia have received 19 international design awards such as Red Dot Design Award, iF product design award, International Design Award (USA), Dieline Packaging Design Awards, Creative Business Cup, Swatch Art Rules, etc. Hereafter the study analyses three internationally awarded design products.

RIGA ChAIR is founded by the architect and designer Aldis Circenis. At the very beginning of the economic crisis the designer understood the need to produce products with a higher added value than those manufactured before. As the company bought moulded plywood factory in 2010, the primary purpose of new product development was to design a product to be produced in the moulded plywood factory. The designer's challenge was to design a stool without any single screw, which, is always a problem in use. He knew that all stools in the market are structurally primitive and very similar. Designer intuitively felt a new opportunity to design a distinctive, attractive and still functional stool. New product development was based on the knowledge of plywood constructive feasibility. By experimenting the designer came to the principle that defined the shape of the stool. The Bloom stool was the first product of Latvia that won the prestigious Red Dot Design Award in 2012.

The award brought not only a good publicity to the company but also the status. The potential distributors are willing to sell Bloom stool in design shops, where prices are high, but the company's interest is to sell more, not exclusively.

Another award winning product of the company RIGA ChAIR is a rocking toy named *Roo* made of a single moulded part. The *Roo* product development was furthered by a critical thought: why several generations have grown up with the same classic rocking horse? Are all the rocking horse redesign possibilities exhausted? The purpose of the rocking toy *Roo* was to create a toy that is constructively simple, minimalistic and its very archetypal shape makes it an intriguing toy. [7]

According to the designer's view both products embody simplicity, naturalness and high functionality values. [8]

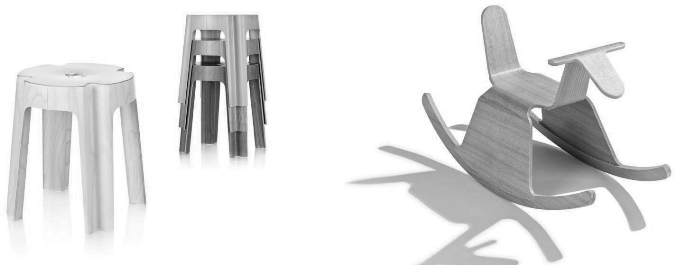

Figure 1. Bloom stool, Red Dot Design product design Award 2012 and International Design Award (USA) 2011, 3rd place. Rocking toy Roo, iF Product design award 2012 and German Design Award 2014, Special Mention. RIGA ChAIR, Designer Aldis Circenis

The design attitude of **Flow Design** by German - Latvian designers Georg Dwalischwili and Janis Karklins „leave-only-what-is-needed" led to the product innovation - the *Cliq* magnetic clothes hanger. [9] "Why keep the metal addition in the hanger design if it's not necessary?" asked designers. Therefore, the aim of designing *Cliq* was functional rearrangement that is reduced to the essential and to surprise and enhance an indispensable everyday utensil. As product values, designer G. Dwalischwili names customer journey improvement, turning shop visitors into brand ambassador, and designing of branding tool for fashion labels and high end boutiques. Also, production is outsourced; *Cliq* is produced locally by using local material - Latvian birch. Designers are convinced that products quality should be controlled locally, thus adding an impact on the local economy. [10]

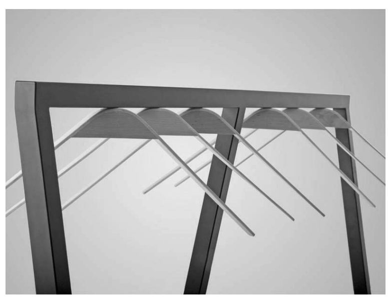

Figure 2. Cliq Premium, Red Dot Design product design Award 2014, Design: Flow Design; designers Georg Dwalischwili and Janis Karklins

GIGI BLOKS is a set of oversized building blocks to foster children`s creativity [11]. The product idea is based on the childhood dream of the GIGI designer to have gigantic blocks for building houses. A few years ago designer wanted to give a present to her daughter, but large, ecologic and environmentally friendly blocks were still not available. The main values of the product are development of children's creativity, spatial and logical thinking, problem-solving experience and communication skills. [12]

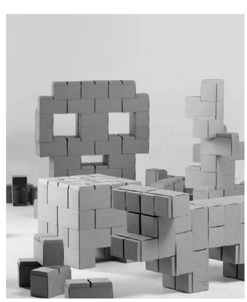

Figure 3. GIGI BLOKS, Creative Business Cup 2014, 2nd place, Designer Ilona Viluma

The purpose of industrially produced and internationally awarded product development is redesign of existing products as new possibilities, based on the material and technological knowledge and the use of new technological possibility. Products embody companies and designer's personal ambitions and values: simplicity, minimalism, use of natural and local materials. All selected designers favoured the view that design products should be manufactured locally or nationally by using local resources. The company that is representing creative industry, promotes social responsibility as children's' creativity development.

3 THE AIM AND VALUES OF DESIGN BACHELOR AND MASTERS DIPLOMA PROJECTS

The product **"Meet-me!"** deals with communication problems in the public space. It offers rearrangement of the environment to foster emotional, psychological and social communication processes. "Meet-me!" was created with the idea to provoke a casual conversation, informal meeting, and relaxed communication in the public space. The designer has recently launched a company to develop the product production cycle.

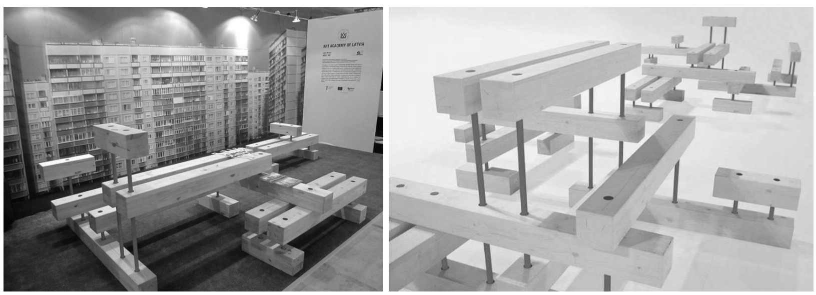

Figure 4. Design bachelor project "Meet-me!", 2012, designer Ligita Breģe, supervisor assit.prof. Juris Krūmins; 1st place „SaloneSatellite WorldWide Moscow 2012" and Eco-innovation award in new product business competition, Latvia, 2014

"KLIKO" is an inflatable portable kids' toy that is designed for indoor use, playing in the yard and even on the water. The purpose of the toy was development of children's creativity that is based on children's desire to build various huts, rods and houses from handy materials themselves. The product is produced from used tents and banners creating the value of sustainable thinking.

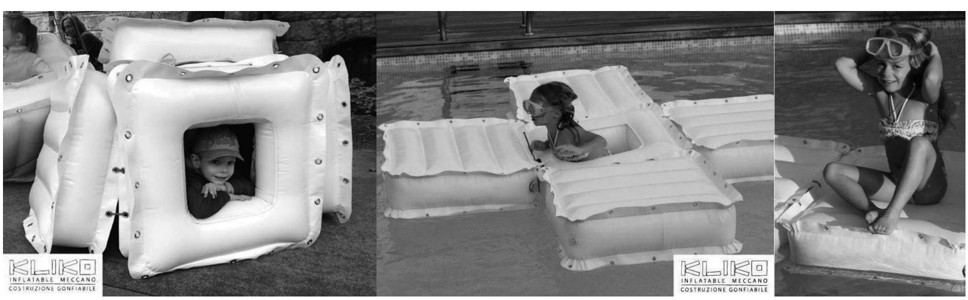

Figure 5. Design bachelor project "KLIKO", 2012, designer Rodions Zenevics, supervisor assit.prof. Ervins Pastors; 3rd place „SaloneSatellite WorldWide Moscow 2012"

"Scense", herbal initiators of senses invite to touch and smell thus provoking sensations and memories. It emphasizes traditions and habits in wellness in the 21st century lifestyle. The aim of the designer was to create additional usability of herbs beyond so widespread tea drinking. The designer is looking for opportunities to develop product manufacturing, by participating in various start-up competitions.

Figure 6. Design master project "Scense. Initiators if senses", 2014, designer Mara Maizele, supervisor assit.prof. Aija Freimane, The best Latvia representing product at Annual Design award Latvia, 2014

The product **"Sleep and Sleeplessness"** [13] resulted from the design research path of insomnia as coincidental innovation. The product as transition object provokes impulses to the central nervous system thus causing relaxation and asleep.

Figure 7. Design master project "Sleep and Sleeplessness", 2012, designer Elita Freimane, supervisor assit.prof. Aija Freimane; the only registered student project patent of the Art Academy of Latvia

In the bachelor and master's project new product development ideation process, students were encouraged to define design project development purpose by using design research and creative thinking methods. The students had to approve "why is it a design opportunity, what is the novelty of the challenge?" Therefore it is not surprising that 70% of all bachelors' and master's projects since 2010 are innovative solutions with an aim to bring good for people by fulfilling a specific need or opportunity. 30% of designed products are redesign of existing products' function, form, and style as new materiality or target audience. Innovative products and services are designed as niche solutions to identity, tradition and modernity of craft, social and universal design, eco-friendly design, creativity, collaborative solutions to everyday needs, whose main purpose is social and ethical reflexions.

New technological innovations in the student designed projects are limited due to the lack of internship system and access to highly technological workshops. To design for a particular enterprise, the secret of the technological process and knowhow of the company need to be met. Due to this, ethical and human aspects as niche design products are faced in the design bachelor and master projects rather than material and technological innovation as product form and function redesign.

However, only two young designers from around a hundred have started up their businesses based on the bachelor or master design projects since 2010. Although all student designed products are based on profound research, the lack of business partnerships prevents the product from promotion into the market and to the user.

3.1 Conclusion - main product development objectives and values

Industrially produced new product development is based on the narrow product development – form and function redesign of existing products in the market. It is reached by using new material-technologies and technological possibilities to obtain new market positions. Niche products are the ones that differentiate countries and communicate particular culture and lifestyle. Limited economic and human recourse opportunities open new potential of creation as new product and service development or new business forms. The following examples mentioned serve as a clear evidence: the booming specialization of creative industries enterprises since 2010 as fashion design and accessory design, such as clothing, handbags, scarves, shoes, hats, jewellery; products developing children's creativity; interior accessories - textiles, candles; web-based service solution; office supplies - blocks, planners, typeface deign, applications and furniture etc. These products can be acquired worldwide via the internet and export trade opportunities. However, research defined, that the ethical and social aspects, especially identity and belonging as transformation of traditions, wellness and health, are important to a creative industry's design specialization of a small economy rather than industrially produced products. Ethical and social issues are the main factors of micro-niche-design enterprises although it is not sufficient for their fast growth and successful development globally. Ethical and social aspects that are included in the early stage of design process, favour design of paradigm shift under the pressure of the global economy but are not reflected in the industrially produced products.

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Chapter 7

Matrices and Assessment

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
3 & 4 SEPTEMBER 2015, LOUGHBOROUGH UNIVERSITY, DESIGN SCHOOL, LOUGHBOROUGH, UK

INTRODUCING RESEARCH IN ARCHITECTURAL DESIGN TEACHING AS A MEANS TO ENHANCE THE DESIGN LEARNING PROCESS

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ABSTRACT
What is important in architectural education? On the one hand, students learn about architecture itself; about designed buildings and surroundings. And on the other hand, they learn how to design architecture. The latter being the study of the process, while the first is the study of the product as a result of that process.
A literature review of the design process brings up that being process-oriented, and not product-driven, is one of the most important skills while designing. But architecture students are also very interested in designed architecture as a result, as a product. So focusing on the process while forgetting the end product of it, seems a very difficult skill to develop.
Integrating the design in a research project can counter this problem. Besides other advantages, like for example positioning the standpoint and the design of each student in a larger frame, the incorporation of the assignment in research also changes the true nature of the project. In fact, the focus shifts from solving a problem to doing research, and at the same time it alters from solution to process.
In a specific case, we redefined an assignment for first year architecture students for a 'townhouse' and changed it into a 'research on dense urban living'. The purposes of the new assignment, and at the same time the resulting documents, do not concentrate on a designed house as a result, but they focus on the student's research as part of a larger investigation of 'urban living'.

Keywords: Research, design process, teaching, architecture.

1 INTRODUCTION AND MOTIVATION

1.1 Introduction and motivation

Architectural education can be analysed in several ways. One way is that you consider architectural education as consisting of architecture on the one hand, and architectural design on the other. The latter being the study of the process, while the first is the study of the product as a result of that process.
A lot of theory about architectural education emphasises that during the design process, designers should be more concerned about the design process than the design outcome. Frederick Matthew [1] states that being process-oriented, and not product-driven, is one of the most important skills in architectural design. Among Ochsner [2], the overall focus of design education is clearly the internalisation of the design process itself. He states that it is not the problems themselves or the solutions alone that are the aim of design education. Rather the aim is learning a personal process of design - a way of thinking about making architecture. Lawson [3] confirms the importance of the process with a metaphor: not just the skill to juggle is needed, but also the judgement of which set of balls to pick up and when.
But this focus on the process instead of the product is not easy, considering that architecture students are also very interested in architecture itself, being mostly the main reason for choosing an education in architecture. Moreover, the focus on the end result is reinforced by the fact that the design process in itself is solution-oriented, meaning that the nature of the problem can only be found by examining it through proposed solutions [4].

And also, in most studio's, mainly the end product is evaluated, sometimes even with an external jury who didn't follow the process at all, thereby moving the focus even more to the end product, All these factors stimulate students to skip real thoroughly investigation of alternatives in favour of a finished product.
So focussing on the process while forgetting the solution or end product of it, seems a very difficult skill to develop. How can we anticipate to this difficulty? Let us therefore investigate the through nature of the process.

1.2 Approach

We will begin this paper with a literature review of previous research on the design process. In this section, we will find out that searching and research are key features of that process. With that theoretical frame in mind, we changed a classical studio assignment and asked students to introduce in an explicit way research in their design process.

2 THE (RE-)SEARCH AS A KEY FEATURE OF THE DESIGN PROCESS

2.1 The design process as a sequence; as a series of searches

Takeda and others [5] describe the design process as a repeated sequence of problem formulation, suggestion, development, evaluation and conclusion. Cross [6] describes 4 essential activities during the design process: exploration; generation; evaluation; communication. IDEO [7] describes 5 phases: discovery, interpretation, ideation, experimentation and evolution. The process of
human-Centered Design developed by IDEO goes through three main phases: hear, create, and deliver. All these models have in common that they describe the design process as a sequence; as a series of searches; or, as Neutelings [8] formulates it; as a quest, a journey of discovery without a map, where only the port of departure is known. And this cycle of searches is repeated until a satisfactory solution is found.
Now this is where research by studio design comes into play because, by definition, research is about searching and thereby, it can help students to focus on the process, as a cycle of searches, in favour of the design product.
So being process-oriented means on the one hand trying to understand what to do when and why, but it surely also means being search-oriented. Or, according to Matthew [1], it means that you know when to change and when to stick with previous decisions, but it also means that you seek to understand a design problem before chasing after solutions.
In fact, also in a literal way, the words 'design' on the one hand, and 'research' on the other, bring along with them a difference in focus. The word 'design' is not only used for the process, but it is also being used for the end product. While on the other hand, the word 'research' contains in itself already the word 'search'.

2.2 Hurried and slow designers

The focus on the search means that the designer must take time to search, to ask questions, to examine alternatives, to investigate all constraints, instead of running in a straight line to a solution. He must take his time to love his experiments [9]. Being slow to fall in love with his ideas. A good project is made slowly. Today it is more essential than ever to insist on having that time for the design process. The architect needs this time not so much for the design production, but for the analysis and subtle balance of all the facets of the social, functional, environmental, economic and contextual problematic of the project. Every commission needs ideas to bring it to life and ideas take time to ripen. A good architect works slowly [10].

2.3 Design process versus design product

Shifting from the end product to the search-process, brings along some other advantages linked with research. Defining a project as a research will position each design project in a larger frame. Framing at the start of the research offers a context and an intention. Framing at the end offers comparisons between different results.
But besides offering a larger context for the design research, it also changes the relations between teacher and student in a design studio in a positive way. The relation between teacher and student

shifts from the knowing teacher and the not knowing student to a collaboration between both; from the teacher who demonstrates and the student who repeats to both suggesting and developing, from an active teacher and a passive student to both being active. And more specifically, the student shifts from being non-critical tot critical; from just answering to also questioning things. And the process shifts from teaching to learning. Educational psychology emphasises the importance of learning over teaching [11]. This shift from passive to active reinforces the learning, following John Dewey's argument that children must be engaged in an active quest for learning [12]. Just having an experience does not necessarily mean that learning has occurred. The important factor in turning experience into learning is reflection [13]. The model of the student as an empty vessel is thereby criticised. In this model, the teacher is to fill the student with knowledge, while the student has to acquire the desires of the teacher, and display that knowledge back to the teacher, unchanged by the students own thinking, desires and ways of knowing. In contrast to the student being 'filled' with knowledge, a dialogic exchange between student and teacher which values both party's prior knowledge and experience, will lead to knowledge being produced. The student teacher relationship becomes one of mutual exchange and collaboration [14].

The move from product to process also meets the principal goal of education. That is to create men and women who are capable of doing new things, not simply repeating what other generations have done - men and women who are creative, inventive and discoverers. The second goal of education is to form minds, which can be critical, which can verify, and not accept everything they are offered [15].

3 CASE: REDEFINITION OF AN ASSIGNMENT FOR A TOWNHOUSE AS A CASE STUDY ON URBAN LIVING

3.1 Introduction and approach

In a specific case, and as an experiment, we redefined the assignment for the first year architecture students of one design studio in the first bachelor. The question to design a 'townhouse' was changed into a 'case study - or research - on urban living', framed by a larger context. The context of densification, explained with 'het lelijkste land' of Renaat Braem [16] and with some of the main intentions of the 'ruimtelijk structuurplan vlaanderen', was offered by the tutors as a starting point, together with a real empty plot in the city of Leuven. The students of this research-studio worked parallel with the students in the other studios in the first bachelor. In the other studios, students worked on the classical assignment of a townhouse. The purposes of the new assignment of the students in the test studio, and at the same time the resulting documents, did not concentrate on a designed house as a result, but they focused on the student's research as part of a larger investigation of 'urban living'.

The project was organised in a rhythm of 5 design weeks, each of them consisting of 3 design afternoons. Students worked together in a studio, whereby almost every design afternoon, a tutor passed by to review their work, individually, or in a group. At several moments during these weeks, we did not only review the student's research, but we also interviewed them about the assignment itself, and about the redefinition of the project into a case study.

3.2 Week 1

At the start of the project the assignment was isolated from its site. We isolated the project from its real context to facilitate the focus of the students on spatial aspects of urban houses. So the students didn't work on the available empty plot during this first week, but started to investigate qualities of spaces and places of urban houses in general [Figure 1]. A frequently recurring research involved the balance between density and spatiality, between contact with the surroundings on the one hand and privacy on the other. Individual spaces were examined separately, but also combinations and configurations of spaces were tested.

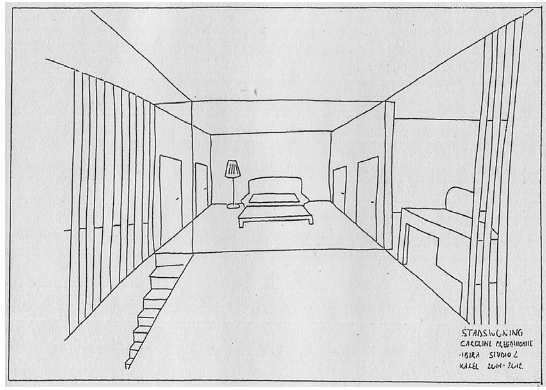

Figure 1. Investigation of spatial qualities of bedrooms and communal space around a roof terrace, by student Caroline

And from the third day on, almost parallel with this research on identities of spaces in dense areas, they started to examine needed surfaces and volumes for typical activities related with urban houses. [Figure 2]. Students were encouraged each time to test several variants, to search for alternatives, whereby the comparison between these variants made the qualities of each of them more tangible. We also asked them to give each variant a specific name, as to appoint the characteristics of this variant.

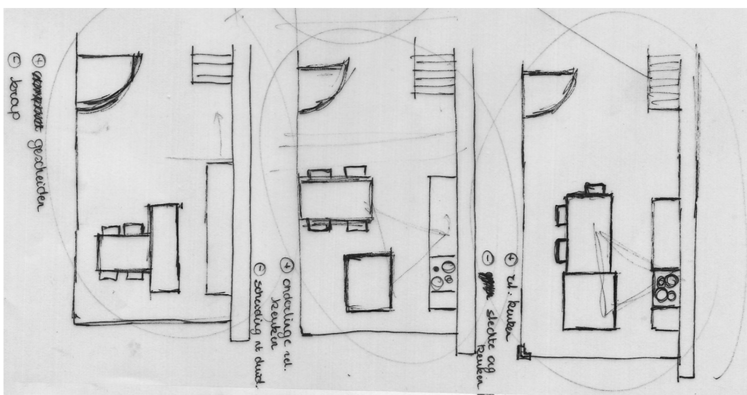

Figure 2. Variants for the activities linked with eating and cooking by student Thomas

This siteless investigation of qualities and quantities of places and spaces was continued during one week. Only after this first week, and after making several small volumetric spatial models of the conceptualised houses, these models were put together on the available plot. The plot we proposed is an empty site for row houses in the city centre of Leuven. Several combinations were investigated before choosing a specific location on this site in the row formed by the houses of all the students of the studio [Figure 3].

3.3 Week 2 to 5

In week two, students started to investigate tectonic and structural qualities of urban houses. As during the first week, several variants were tested, whereby students got already much easier in the rhythm of alternating divergent and convergent.

During the third week, they combined their research of the second week on solids with their research of the first week on voids, trying to match the different constraints, again by investigating several possible combinations of solutions [Figure 4].

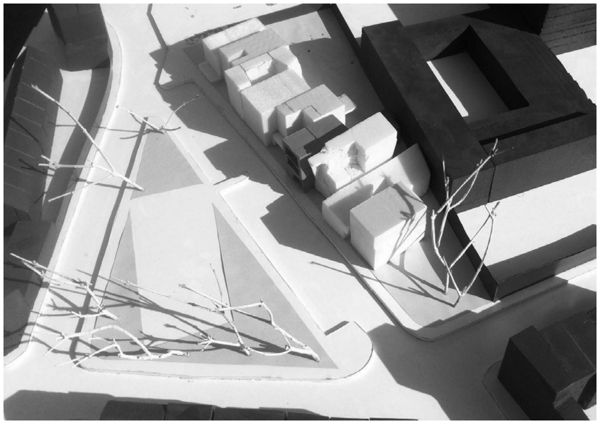

Figure 3. Model of site with a row of 9 houses

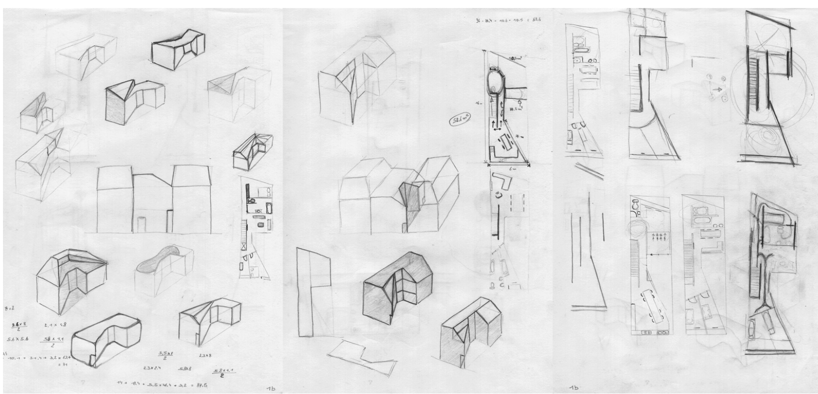

Figure 4. Matching of all design aspects by student Damiaan

In week four and five, students started to elaborate one of the possible solutions. Thereby, the assignment shifted progressively from extensive divergent research to more convergent problem solving. It shifted from testing several variants to merging the different constraints into a consistent solution. And at the same time, the assignment also shifted from research to design [Figure 5].

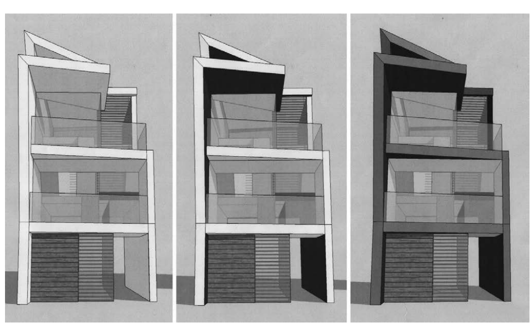

Figure 5. Testing of several variants of materialisation in interior and facade by student Thomas

4 CONCLUSION

At first sight, the design search and results seemed to be similar to that of any well done design process. And in fact they are indeed similar to that of an exemplary design process. But when we compared the results and documents of the students of the 'research-studio' with those of the other parallel 'design-studios', we could pinpoint major differences. Students of the research-studio had produced much more research documents and had examined much more variants in each phase of the process, in a much more systematic way. The definition of the assignment as a research project, that only at the end turned into a real design project, greatly helped the students to shift the focus from the final result to the design process. Previous research showed that this helps designers to get closer to such an exemplary design process. We did not adapt the project to expect groundbreaking research from students during the first year of their education, nor to let them analyse every step of their design process. But we changed the assignment as a means tot let go the focus on the end product and to get students concentrating on designing itself: the iterative process in which divergent and convergent researches alternate and in which a cycle of problem formulation, hypothesis, testing and evaluation is repeated.

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RP OR NOT RP: THAT IS THE CO-CREATION QUESTION

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ABSTRACT
The growth of rapid prototyping (RP) appears to show no sign of slowing. Within industry, recent advances in material development have driven the increased adoption of RP technologies for manufacture. Businesses and hobbyists have embraced the availability of low-cost, desktop 3D printers. Schools and universities have enthusiastically integrated 3D printing into their teaching, particularly within the fields of design and engineering.
However, there is evidence that the popularity of RP is driving a disconnection between the worlds of industry and education. Recent comments by Apple's head designer have highlighted a shortage in vital practical design skills among new graduates. These comments follow announcements of the closure of practical workshops within the design departments of several universities. Recent academic research has also been increasingly concerned about the educational benefits of utilising RP within design teaching.
These developments raise a number of important questions for educators within design and engineering (D&E):
- Can the use of RP technology affect the development of other essential skills required in D&E?
- Is experience of RP technology an essential requirement for today's D&E graduates?
- Is practical workshop experience an essential requirement for today's D&E graduates?
- What view does the design industry take on these questions?

Drawing on new research into the experiences of Bournemouth University's BA/BSc Product Design students and industry professionals, this paper explores whether universities are providing students with the correct skills for today's design industry; how RP affects the traditional design education approach; and whether the concept of co-creation through the combination of traditional physical fabrication and rapid prototyping is appropriate.

Keywords: Rapid prototyping, RP, traditional prototyping, 3D printing, model making.

1 INTRODUCTION

"So many of the designers that we interview don't know how to make stuff, because workshops in design schools are expensive and computers are cheaper. That's just tragic, that you can spend four years of your life studying the design of three dimensional objects and not make one." [1]
These words were spoken by Apple's head designer Jonathan Ive at London's Design Museum in November 2014. Remarkably for a senior vice president of the world's biggest technology company, Ive bemoans the reliance on digital tools over practical skills. His words highlight a crisis within current product design education.
Since the birth of stereolithography in the early 1980s, the role of rapid prototyping (RP) has grown with gathering pace within industry. RP's ability to produce models with arbitrary shapes more quickly, and at a lower cost, than traditional prototyping techniques has driven its popularity in the production of evaluation aids, concept models, and master patterns. More recently, rapid manufacture (RM) has increasingly enabled companies to forego traditional manufacturing processes in applications where a relatively small number of parts are required. Airbus's decision to include over 1,000 printed parts within their A350 XWB jet [2] is just one illustration of RM's advantages when time and financial constraints are a driving factor. Industry's adoption of RP and RM is clearly set to continue expanding, with additive manufacturing industry worldwide sales predicted to reach $6 billion by 2017 [3].

Within the consumer market, the popularity of low-cost, desktop 3D printers also shows no sign of slowing, with sales forecast to accelerate to one million machines per year by 2018 [4]. Schools have also embraced the new technology. Makerbot's stated aim to place a 3D printer in every US school, and Ultimaker's intention to do the same in the UK, will produce a generation familiar with .stl files and build envelopes.

Given this background, it would seem inevitable that higher education (HE) establishments should be replacing lathes with printers – and many are. Anyone who has visited London's New Designers Exhibition over the past few years – a showcase for the UK's brightest new graduate designers – will have noted the gradual demise of the hand-made prototype. Bucks New University, Portsmouth and Falmouth are just three of the universities to announce workshop closures in 2014 [5][6][7].

The authors of this paper have viewed these developments with increasing concern. The ethos of all the design and engineering courses at Bournemouth University (BU) has been based on a holistic approach within the remit of each course. A common factor has always been that the final product must be designed for manufacture; hence every course (with the exception of Industrial Design) has had access to the design and engineering workshops, with the teaching of practical skills a core requirement.

As experienced design and engineering practitioners in both industry and education, the authors feel that the relative roles of RP and practical workshops require re-evaluation, now more than ever. To that end new research was conducted which aimed to uncover some current truths regarding the use of 3D printing and model making workshops and how they are viewed by students and industry professionals.

2 METHODOLOGY

In order to understand design practitioners' and design students' views of rapid prototyping verses traditional prototyping and inform further discussion a data collection activity was conducted. A basic qualitative and quantitative questionnaire delivered by Survey Monkey™ was determined to be the most suitable form of tool for data collection.

Data collection was solicited from three sources: final year BSc and BA Product Design students studying at Bournemouth University, all of whom had completed an industrial placement; Product Design academics at Bournemouth University; and design professionals currently employed in design management or design training at Dyson Ltd.

The participants were invited to answer a series of questions regarding their own views and experiences of RP versus traditional prototyping in education and practice.

3 FINDINGS

There were 40 responses in total: 27 from undergraduate BU Product Design students, seven from BU Product Design academics and six from design professionals employed at Dyson Ltd.

It is apparent that the majority of respondents (95%) has or intends to use rapid prototyping in their professional practice (Figure 1). The uses were wide-ranging but by far the most common use of 3D printing was for prototyping (Figure 2). The majority of design professionals used rapid prototyping across all activities within the design process.

Figure 1

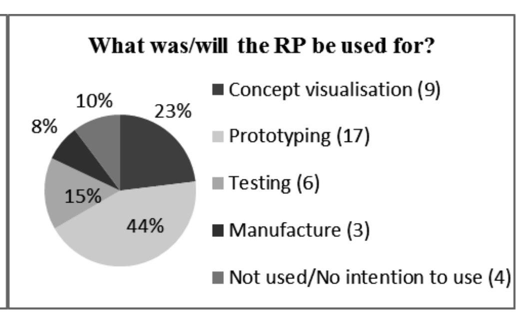

Figure 2

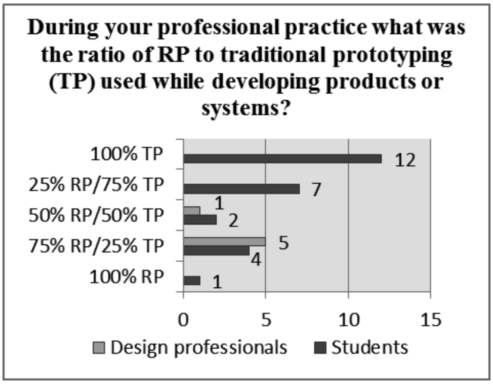

Figure 3

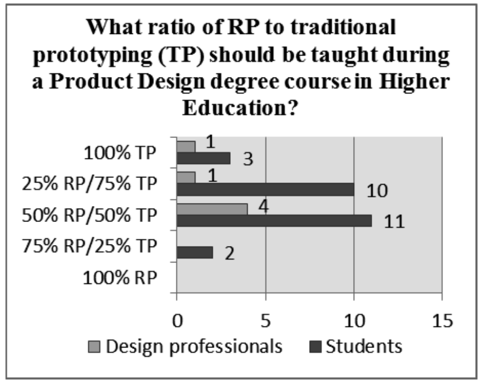

Figure 4

When asked what the percentage ratio of use between rapid prototyping and traditional prototyping the majority of student respondents (around 72%) had used 75-100% traditional prototyping during their professional practice (Figure 3). This is in contrast to the design professionals of whom the majority (around 83%) utilised 75% or more rapid prototyping during their professional practice. This may be due to specific research and development practices used by Dyson Ltd, but are in all likelihood an indicator of what progressive product design and manufacture companies are doing.

When it comes to thoughts on what should be taught during a typical Product Design degree course most respondents agreed that the split should be around 50% - 75% traditional prototyping skills to 50% - 25% rapid prototyping skills (Figure 4). Interestingly the Head of Design at Dyson qualified his view that only traditional prototyping skills should be taught in HE with the observation that RP skills could easily be learnt when working in industry.

In addition 95% of respondents indicated that a working knowledge of traditional prototyping was essential for design graduates (Figure 5) whilst only 75% indicated that a working knowledge of RP was essential (Figure 6).

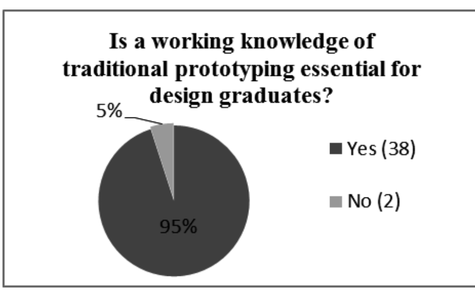

Figure 5

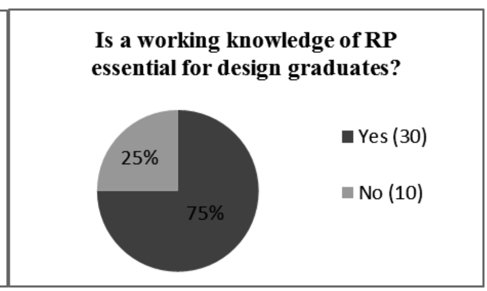

Figure 6

When asked to give their qualitative views on the subject the majority of students and professionals agreed that traditional prototyping skills are an essential element, particularly in the earlier stages of the design process. The following comment from a design professional is typical:

"We see grad[uate]s that are now too quick to CAD something up and then RP it rather than go to the workshop and cobble something together to test the basic principles first. It wastes time and money doing it. That approach is fine once you have done some rudimentary work beforehand."

Students related similar experiences with traditional methods during their professional placements:

"When you work in a design consultancy, for example, CAD and RP are the last stages of the design process. The way the designers communicate is through sketches and crude model making. This is where the most important discoveries in the design process are made. It is this creative, fast paced and dynamic way of thinking that produces innovative ideas and the unique selling points which will determine the success of your product."

The value of traditional skills in encouraging empathy for materials and manufacturing methods was also stressed. Another Dyson professional commented:
"Machining, CNC, lay-ups, mouldings, etc. all have deep roots in manufacturing methods which give designers good empathy for how a design could be manufactured. It's manufacturing empathy that's lacking as a result of too much RP emphasis in HE."
It is interesting to note that even though Dyson Ltd utilise a high percentage of RP work compared to traditional prototyping, the design managers have very strong opinions on the importance of teaching traditional prototyping skills in higher education.
It was generally acknowledged that appreciation of RP was important but should be taught as a compliment to the design process rather than a direct replacement of traditional prototyping. Concern was also expressed that alternative RP processes should not be side-lined:
"Design education should also make sure students know what RP processes are available and under which circumstances they should be used. I've found some universities have a strong focus on FDM machines when in practice I've found SLA to be most essential (apart from very early spacial models, in which SLS works very well)."

4 DISCUSSION: RP IN EDUCATION

The pragmatic and economic advantages of utilising RP have been the primary driving force behind its adoption in HE. As in industry, the expense of installing new equipment has been rewarded by savings in workshop manpower and space. Prototype build times have been reduced, and the burden of health and safety requirements significantly lightened. Though material costs and limitations have been problematic in the past, the introduction of cheap plastic filaments and a wide range of revolutionary printing materials – including even carbon-fibre and Kevlar – have largely dissipated these criticisms. Even full-colour 3D printing has become a reality.
While these practical arguments are compelling – and apparently conclusive in their support for RP - the educational case is less clear-cut, and it is this area that concerns the authors of this paper. The research findings highlighted particular issues with the use of RP during early design development and these deserve further discussion.
The benefits of using traditional methods and materials (such as Styrofoam, card and modelling clay) during these early stages are well-documented, and no CAD-based system can provide the level of instant scalar and tactile feedback provided by hands-on modelling. Moreover, while CAD encourages students to create finished designs with precise dimensions and geometric shapes, traditional modelling produces a more "fuzzy" approach to early modelling, the significance of which has been widely established by previous research [8][9][10]. CAD modelling is also much less likely to produce the happy design "accident" – those occasional but significant instances when a design can take a major turn due to a chance discovery or the shape of an offcut of material [11].
Many researchers, such as Gerber & Carroll [8], accentuate the importance of quick design iterations with a high failure rate, in order to increase confidence in the validity of the final design; in the words of Craig Sampson, to "measure success by the height of the trash pile" [10]. While methods like foam modelling can produce a larger number of different models in a short time compared to 3D printing, students can often be reticent to undertake multiple design revisions due to the effort required: each model needs to be started from scratch, whereas a CAD model can be edited and reprinted with ease [12][13].
Undoubtedly, design development can be hampered by the practicalities of modelling with traditional methods. This may be due to the limitations of the materials or processes or due to the skill level of the student themselves [14]. Many design students will find traditional modelling frustrating and outdated. Wilgeroth and Gill [15] claim that RP relieves students from the "burden" of learning model making skills. The authors regard this observation as short-sighted in the extreme. Although the process of making models by hand is arguably more difficult, costly and time-consuming, the educational benefits to the students are vital. An understanding of the behaviour and characteristics of materials is perhaps the greatest benefit, and it is the disconnect between material and form that particularly worries Jonathan Ive:
"One of the things that drives me potty is this idea that you can have a random shape, and then you think let's make this bit in wood and that bit in plastic….You can't make those decisions, you can't read about it, you gain that experience by making."[1]

This comment chimes with the authors' own research findings that students and professionals alike consider practical, hands-on model making essential for gaining manufacturing empathy. Ironically, although the health and safety benefits of 3D printing have been championed over workshops, BU believes that exposing students to the potential dangers of the workshop and providing them with the skills and knowledge to use machines safely ultimately produces safer, more confident designers.

However, Forkes [16] noted the frequent discrepancy between students' design drawings and their final models, and his argument that RP models will retain more of the designer's original vision is compelling – though this is only true if the student's CAD skills are up to the task. The phenomenon of "design for model making" was ably described by Wilgeroth and Gill in 2006 [15], where students consciously (or subconsciously) create designs that they know they can create in the workshop. Although their assertion that RP eliminates this issue is debatable, it is certainly true that designing within the digital realm can enthuse students, motivating them to produce more complex and extravagant forms [17][18][19]. While this does not necessarily ultimately produce "better" designs – and some students (and possibly educators) may be guilty of confusing higher quality models with better design - it does broaden the possibilities, and levels the playing field for students of differing modelling abilities [14].

The broadening of possibilities raises the issue of design for manufacture. In 2012 Campbell, Bourell and Gibson [20] embraced RP's capability for allowing students to be "encouraged to ignore the design-for-manufacture limitations they have been used to", while Helbling & Traub [12] welcomed designs "no longer hindered by manufacturing difficulty". These comments assume that today's product design and engineering graduates have no need to understand the limitations imposed by traditional manufacturing methods. In the opinion of the authors, this is a severely misguided view. As one of the main aims of the design educator is to prepare the students for their professional life in the industry, it has always been deemed necessary to use industry-standard processes. Despite the increasing popularity of rapid manufacture, the expense and practical limitations of the current RM technology and materials have ensured that it still occupies a niche position within the manufacturing industry. In removing the requirement for such staples of design as draft angles and tooling standards, RP discourages students from engaging with the eventual method of manufacture and gives them a false sense of what may or may not be economically or practically viable.

However, as stressed in the authors' research, educators are equally guilty of leaving students ill-equipped if insufficient attention is given to RM. Undoubtedly the proliferation of printed products will only escalate. 3D printers offer students a valuable insight into the current and future possibilities of RM, and a sobering reminder to treat media hype with a pinch of salt. The number of different forms of RP is increasing rapidly, each with their own specific design-for-manufacture considerations, and all of these should be taught alongside traditional manufacturing. In the words of Ford & Dean [17]: "Teaching should not be restricted to innovative practice in the application of new technology but all appropriate methods, old and new."

5 CONCLUSION

Bournemouth University's practical workshop facilities have received much praise in recent years from external examiners – for example from Dr John McCardle of Loughborough University in 2013: "Bournemouth is clearly delivering a modern and a pragmatic approach to product design, supporting extensive CAD use and elements of digital prototyping, but importantly also encouraging a hands-on approach in workshop practices." The importance of teaching traditional model making skills was similarly reinforced by the vast majority of respondents to the authors' own research – both student and professional. This appears to support the concerns of Jonathan Ive, and highlights the folly of closing workshop facilities. By neglecting the teaching of practical skills, design educators may well be damaging their students' employability, as noted by one of Dyson's design managers:

"As far as I am aware Bournemouth University seems to still place a great deal of importance on traditional prototyping and I feel this is very beneficial in providing students with practical skills that some, but not all, employers may look for. I think it more likely that an employer would pick someone with practical workshop experience over RP experience as there is more "skill" involved in traditional prototyping. This probably greatly depends on the employer however."

However, the authors' research also revealed some dissatisfaction amongst students with regard to the lack of emphasis placed on RP at BU, and this may be of equal concern. If we are to take note of what students and industry are telling us, product design educators must aim to strike a balance of true co-creation between technology and tradition: "RP is merely a process that enables certain parts to be made to work alongside TP. Both are necessary and should be taught to complement each other, giving students the knowledge to know when and why one may be used over the other is essential."

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AN INVESTIGATION OF WHAT FEEDBACK STUDENTS RECOGNISE AS FEEDBACK

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ABSTRACT
The paper reports on a study conducted with final year undergraduates on a product design course, in the UK, to attempt to better understand how they both interpret and respond to feedback on their academic work. The starting point for this study was the relatively poor scores attained for the elements of assessment and feedback in the National Student Survey (NSS) results for this course. The paper draws upon an existing body of literature around assessment and feedback related to the NSS results nationally. Based upon the literature an intervention relating to an element of assessment was made with these students and data collected on the students' response to this intervention. The results of analyzing this data suggest that while students' responded positively to some aspects of the intervention it is apparent that students' still struggle to understand how to deploy the feedback to improve their work. The final part of this stage of the research involved a second intervention with the same student cohort that attempted to ascertain what they would like to receive in terms of feedback.

Keywords: Assessment and feedback, product design and engineering design.

1 INTRODUCTION

This paper reports on research that considered how undergraduate students in design understand what feedback on their academic work actually is and how to use it and is closely aligned to the conference theme Design & Engineering Pedagogical Practice. Issues related to students' not understanding feedback have been highlighted in the UK by the annual National Student Satisfaction Survey (NSS) scores for some years [1] but for the purpose of this paper it is important to note that the feedback to which the NSS refers is considered to be written formative feedback on assignments.

The literature surrounding the 'feedback gap' is wide but distinguishes the meaning of feedback as falling into five categories, ranging from correction of understanding to a student's longitudinal development [2] but research suggests that the different understanding of feedback held by tutor's and students' contribute to confusion about what feedback actually is [3].

This paper reports on a study carried out at Wessex University with final year undergraduate students of Product Design that was aimed at understanding what its students consider feedback to be. NSS scores are consistently weakest for assessment and feedback for this course. As part of the assessment of their final year project work all undergraduate design students at Wessex are required undertake a Concept Design Viva (Viva 1) and a Detail Design Viva (Viva 2). Although marking criteria has been provided in the Project Handbook and feedback has been always been provided, qualitative comments from the NSS suggest that students do not see this as feedback as a quantitative mark is not given. Hence, the introduction this academic year of a new feedback form which while still not providing a quantitative mark does indicate a profile against each marking criteria. This study sought to firstly, determine what these students' think of as feedback, and secondly, whether the changes made to the written feedback have produced a positive response from students' in terms of recognising it as feedback and seeing its usefulness.

2 LITERATURE REVIEW

The literature surrounding the 'feedback gap' is wide but suggests that the meaning of feedback falls within a typology of five modes: "correction of understanding; reinforcement; forensic diagnosis; benchmarking to a student's longitudinal development (feed-forward)" [2, p278] but research suggests that the different understanding of feedback held by tutor's and students' contribute to confusion about what feedback actually is [3]. Orsmond and Merry [3, p126] suggest that students 'do not hold a homogenous view of feedback and that students' find it difficult to act on feedback unless discussion is also held with the tutor. Results from the same paper suggest that most feedback is largely focused on correction and praise with few tutors providing feed forward, that is, how to approach future work. Interestingly, the results from the students suggest that the majority use feedback into order to work out what tutor's requirements are which leads to "not developing into biologists, but merely mimics of biologists." [3, p133]. A significant recommendation is to give feedback that requires self-assessment and getting students to collect feedback together and to consider trends with a personal tutor.

Price et al [2, p279] make the important point that "feedback can only be effective when the learner understands the feedback and is willing and able to act on it", and that the ability to do this is affected by the emotional impact of the feedback. Similarly to Orsmond and Merry, Price et al suggest that feedback is often viewed as being on student work that has been completed and not seen relationally to the future and that students' find it difficult to see feedback as useful to the whole course experience and not just a specific unit or assignment. Nicol [4, p501] supports the view that feedback requires something more than the written form but recognises that in a mass higher education system the "written comment has become detached from the supportive context". He suggests a model based on a dialogical framework which includes getting students to identify the criteria for assessment to establish a context as well as asking them to identify the kind of feedback they would like as well as using the concept of peer-critique. Race [5] however, looks at feedback more broadly and suggests that formative feedback is perhaps more important than summative. He [slide 13] posits methods for being able to:

1. Give better feedback to more students in less time.
2. Choose feedback methods where the student learning payoff is high, and stop wasting your time on feedback that isn't used.
3. Prevent marks from detracting students from useful feedback.
4. Use student self-assessment as a way of giving them really useful feedback.

3 THE INTRODUCTION OF AN INTERVENTION

Both the NSS 2014 data related to the questions on Assessment and Feedback for Product Design at Wessex University:

1. The criteria used in marking have been clear in advance - 46%
2. Assessment arrangements and marking have been fair – 60%
3. Feedback on my work has been prompt – 48%
4. I have received detailed comments on my work – 48%
5. Feedback on my work has helped me clarify things I did not understand – 48%

   and internal feedback, known as MUSE, taken from final year Product Design students on their final year project Nov 2014,

6. Feedback on my work has helped me clarify things I did not understand – 47%
7. Feedback on my work has been prompt – 50%

Indicate a clear issue with assessment and feedback and that students' perceptions of the feedback they received did not match those of academics, a phenomena confirmed by the literature.

Race, reporting on the outcome of academic staff input into a workshop run at Wessex University in Nov 2014, demonstrates that academics do recognise most of the best practice identified in the literature, such as using peers; discussion and dialogue rather than written [5, Slide 30]. Race also offers advice such as linking feedback to learning outcomes; providing it at the beginning; using it to clarify standards and expectations and stop them concentrating on the mark.

Taking inspiration from the literature, and particularly from the Race workshop, a new feedback form was devised (see Figure 1) for the first viva which assessed students' conceptual design (Viva 1). As the adoption of this form was new, an explanation to its use was provided to students prior to the assessment taking place. In addition to using this form for written feedback students' were also given the opportunity to have a dialogue with their personal project supervisor regarding their performance. There were 10 academic staff members engaged in supervising Product Design final year projects when this study was conducted.

Unit:	**Design Projects 3**	**Name :**	
Level :	**H**	**Hand-in date:**	
Assignment No:	**Viva 1**	**Supervisor :**	

Lecturer Feedback
For Viva 1 Concept Design you are expected to:

	Below Threshold	Threshold	Good	Very Good	Excellent
Have a complete final concept design and provide evidence that the design process is being followed.					
Have a final concept design that satisfies the market in terms of customer, price and quantity, provide evidence of research and justify the technical feasibility of their choice.					
Discuss function, materials, manufacturing, aesthetics and ergonomics with defensible reasoning.					

What are the areas of improvement needed?

Figure 1. New feedback form

4 METHODOLOGY

This research is interested in determining the perceptions of feedback held by product design students at Wessex University and whether the intervention made to the nature of feedback on the first piece of assessment for their final year project changed those perceptions. The study adopted a qualitative methodological approach, and is planned to be the first in a longitudinal sequence of studies.
To investigate whether the changes made to the method of feedback for Viva 1 had changed students' perceptions about feedback; a questionnaire was devised and distributed to the student cohort a few weeks after they had received the feedback. The questionnaire adopted a Likert Scale, ranging from 'definitely agree'/ 'mostly agree' to 'mostly disagree'/'definitely disagree' as the basis for collecting empirical data. This provided an opportunity for comparison to be drawn in relation to the data obtained from the NSS 2014. To obtain a level of richness that cannot be obtained from Likert Scale survey the questionnaire included the opportunity for respondents to add their own comments against each question. The questions were adapted from the NSS as well as from the literature:

1. Do you think the criteria used in marking were made clear in advance?
2. Did you understand how the marking criteria were going to be applied?
3. Do you now understand how you performed against the marking criteria in Viva 1?
4. Do you think you have received detailed comments on your project work to date?
5. Do you understand what you need to do to improve your project work for the future?
6. Do you feel the information provided in the proforma was useful for the progression of your project?
7. Do you think the comments on the proforma on your work has clarified things you did not understand?

Formal ethics approval was obtained prior to the commencement of the study, the participation was voluntary and individuals were free to withdraw at any time. Anonymity has been maintained for both individuals and institution.

5 RESULTS

The questions posed in the survey were broadly focused around a binary divide. On the one hand, an exploration of student perceptions of the feedback mechanism was made (questions 1, 2, 4 and 7) and on the other an enquiry into whether the information fed back to students (questions 3, 5 and 6) developed their knowledge. The work of Hattie and Timperley [6, p86], who provide a conceptual

analysis of feedback, suggest these latter questions, which explore ‘how am I going?’, ‘what to do next?’ and ‘where am I going?’ are essential for effective feedback.
Figure 2 shows the overall results of each question in the questionnaire.

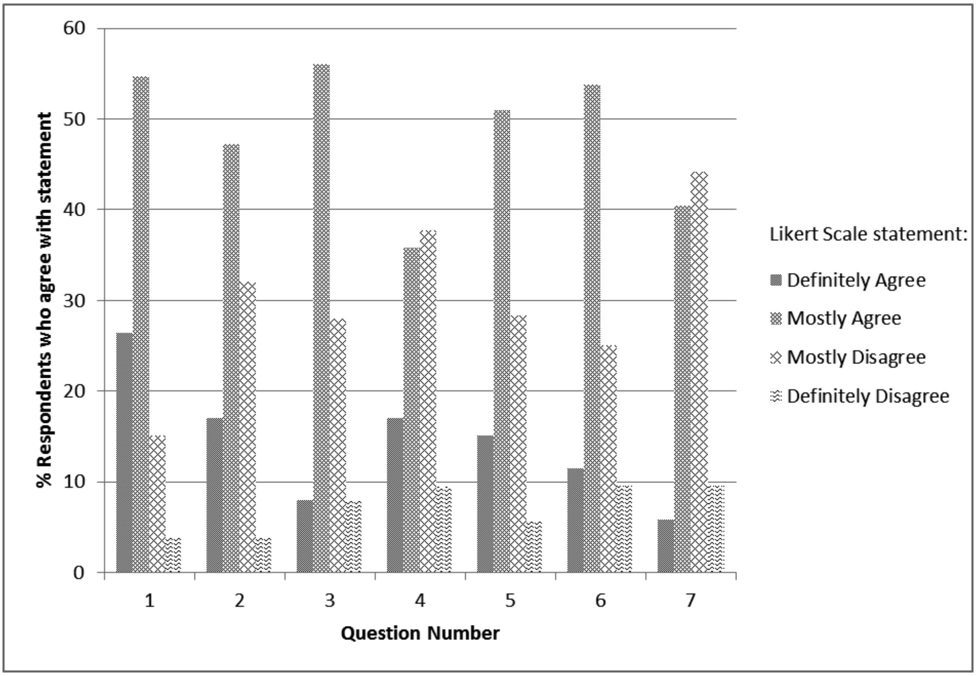

Figure 2. Results of Questionnaire

Ninety-one per cent (n=53) of the final year product design student cohort participated in the survey and of these a high proportion, slightly over 81% (n=43), considered that they were aware of the criteria used in marking in advance of undertaking the viva (question 1) . Of these, over a quarter (26.4%, n=14) ‘definitely agreed’. However, just under two thirds (64.2%, n=34) considered that they did not understand how the marking criteria would be applied by their lecturers (question 2). Whilst one student commented that s/he was *“given the information … and individual lecturers made sure we knew what to do”*, the majority of students who commented believed the marking criteria to be *“too broad”* and *“open to interpretation by the assessors”*. This suggest that in undertaking an assessment students’ have mimetic tendencies as they model their practices on the form which they perceive as the best way to obtain higher marks and not necessarily in how they might develop as product designers. This is an interesting observation as the work of Orsmond and Merry [3] indicates that students will also use their feedback in this way.
Student perceptions of the effectiveness of the varying feedback practices that have been adopted by the unit teaching team, for example, the weekly one-to-one and group scheduled tutorial sessions, appear to be less polarized, as 52% (n=28) indicate that they have received detailed comments on their project work (question 4), whereas slightly under half (46.2%, n=24) reported that the written responses made by their tutors on the *new* proforma (see Figure 2) clarified those things that they did not understand (question 7).
In response to the three questions that correspond to the themes of feed up, feedback and feed forward which are argued as being necessary for effective feedback, students responded similarly to each of them. When asked whether they felt the information provided in the proforma was useful for their progression (question 6) 65.4% (n=34) agreed that it was with comments that it *“found holes in my project that I hadn’t considered”* and *“it let me know I was going in the right direction”*. Several students, however, commented upon the brevity of the feedback and typically described it as being *“too vague to be useful”* or *“scarce at best”*. In terms of the advice that reflects on ‘how am I going?’

[6] just under two-thirds or 64% (n=32) of the respondents confirmed that the feedback proforma provided them with an understanding of how they performed against the marking criteria for Viva 1 (question 3) but their comments suggest that this was because they also discussed their performance with their individual supervisor. In considering the feedback on what to do next to improve their project work for the future (question 5), 66% (n=35) of the respondents once again responded positively though felt they *"could be more detailed and have different lecturers opinions"*.

6 DISCUSSION AND CONCLUSIONS

The intervention was clearly successful in increasing the percentage of students indicating that the marking criteria was clear in advance – 81% after the intervention compared to 46% in NSS 2014, though it is recognised that the dataset was limited to ninety-one percent of the students from an individual student cohort.

The notion that feedback requires something more than written, i.e. there is a need for dialogue is confirmed in the results of this study. Students received written comments on the proforma in Figure 1 but at the same time were able to have a dialogue with their project supervisor, while 64% indicated the proforma did explain their performance (question 3) this was appears to be more associated with the discussion with the supervisor.

However, other results were more mixed, comparing question 4 (52%) in the questionnaire with the similar one in the NSS2014 (48%), the results are not significantly different, this despite in both groups the students received written comments along with a discussion with their project supervisor, albeit the cohort in this study received written comment on the new, more structured, proforma.

In terms of understanding how to improve their work (questions 5 & 6) the responses were positive 66% and 65% respectively yet this was in marked contrast to question 7 which on face value would appear to indicate a contradiction. If you know how to improve is it not implicit you have had things clarified you did not understand? Question 7 in the questionnaire used in this study scoring 46% while the same question in MUSE scored 47% and in NSS 2014 - 48%. Thus, students' responses suggest that there is still an issue related to students' understanding of what do with the feedback they receive. How students' make sense of feedback and interpret it for feed-forward is an issue that arises in the literature.

The qualitative data received as part of the MUSE feedback, which was taken after the students' had had significant formative feedback on their project proposals but had not yet had a summative assessment, also largely indicates that final year students' perceptions of feedback generally concur with the notion identified by Nicol, that feedback is associated with written feedback on assignments.

Across all of the comments made against each of the questions posed, respondents frequently said that they would have preferred to have received a mark for their work and that there were inconsistencies with the commentary provided by their different tutors. Whilst it is clearly important to ensure parity of treatment, and to demonstrate reliability in providing a grade, Rowntree [7] suggests, that in complex situations, for which a final year design project assessment falls, there are clear benefits for students to receive variation in their feedback. This is because of the effect of *scaffolding*, a metaphor which was adopted by Wood, Brunner and Ross [8], whereby the feedback is broken down by different assessors providing a number of perspectives. Adopting a model for scaffolded instruction, requires the role of the tutor to be that of a facilitator of knowledge and therefore encourages students to take greater responsibility for their individual learning. This was recognized by at least one student who responded with, *"the comments, one-to-one meetings and my personal reflection helped me to understand"*.

A similar proforma was used for Viva 2, detailed design viva in March 2015 with the same cohort of students'. In order to attempt to improve the scores for questions 4 and 7 the cohort was asked how feedback could be improved prior to viva 2 by sharing the proforma to be used for Viva 2 and asking them to redesign it as a suggestion from the literature [4] is to ask students the kind of feedback they would like. This resulted in a general consensus from students' that the proforma was appropriate.

As indicated earlier this study is part of a planned longitudinal study that will look at tracking students' perceptions of feedback throughout their journey through university. Hence, the next data collection phase will use a questionnaire combined with the concepts from the literature to determine the perceptions of what feedback is, of first year students on design and engineering courses. These same students will subsequently be surveyed during their second and final year studies to determine if this perception changes. While it will be important for consistency to continue relating outcomes of the further research to the NSS results, for the future the 'respondent pool' will be widened to include all final year students studying Design and Engineering at Wessex. Instead of restricting data collection to a single research instrument further studies will also adopt the use of interviews, either individually or through focus groups to further investigate the notion of mimicry as posited by Orsmond and Merry [3].

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IS VIDEO FEEDBACK IN HIGHER EDUCATION WORTH A BYTE?

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ABSTRACT
Feedback can be given in various situations, like after examinations, project work, and course completion. It is widely accepted that feedback is important for students' learning, and it can be used in various ways, such as, written, face-to-face, and with the assistance of video recordings. This study focuses on the use of video recorded feedback to gather knowledge on how video recorded feedback can enhance the students learning. Since feedback in the study was given *in* video recordings, an alternate way was introduced, which add further insights for teaching and learning at university levels. The results showed that 94% preferred video recorded feedback over written feedback and they, in general, preferred face to face feedback (59%). Although, follow-up questions showed that the students found the recorded option beneficial since they could review the video several times in order to see and hear exactly what was stated and what part of their work it related to. In conclusion, video feedback of student work was perceived to be beneficial and the students and the teacher positively accepted it.

Keywords: Feedback, higher education, teaching, video feedback.

1 INTRODUCTION

Recent assessment research focuses on the core of the teaching process and is closely related to Dewey's educational ideas, which focuses on the student's learning experiences. This includes thought and action, which are intertwined in meaningful activities. Teachers actively stimulate the individuals' learning and one such stimulation, important for student learning, is feedback [1][2]. The value of these findings has not been applied in and adapted to higher education, nor is it yet clear, if they are applicable. Although, there are many connections since individual learning is assessed in both levels.

Each individual has his or her own conceptions and this also applies to one's performance in school and how assessment is done. A student may feel that he or she is doing their best at all times and that is why the student may find it difficult to notice their development. One perspective is that if the students could see their personal development, it might help them in their learning progress [3] and communication through conversation, where teachers and students discuss learning and development, is an important basis to put into words the content of the assessment. Students need to metacognitively understand what needs to be developed so that they can work on their continued development [4]. Since the teacher is essential for the student's development of metacognition [1][3], its continuity in the relationship between teacher and student is required. For this to work the school needs to build long-term relationships so education will lead to learning [1]. Learning processes including teacher-student interactions are not limited to physical interaction, however, it is common for schools to summarize student performance using grades and exams [2].

Feedback is essential to help the student to progress in their learning process and achieve their goals. Therefore, how the feedback is communicated is very important, since it is given in relation to ones' performance. This paper defines feedback as "information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding" [5][6]. Winne and Butler emphasize that the material must be understood for it to be used effectively: "Feedback is information with which a learner can confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, metacognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies" [6]. Kulhavy describes feedback as correcting the performance and giving recommendations for further improvement [7]. However, Bailey and Garner's findings show it is not clear that written feedback is accepted as beneficial for students; teachers in higher education display varied perceptions of its value [8]. Teachers' and students' different perceptions are influenced by, for example, tradition or institutional requirements, which can affect what use students make of the feedback [8][9]. The notion of further improvement has been shown to produce positive effects on student achievement, motivation and commitment to the effort [10]. That is, formative feedback is not just about delivering information about student performance; it also needs to contain information on how the student can change the way they think or the way they act in order to achieve the learning outcomes. Effective feedback must answer three major questions, which pertain to feed-up, feed-back, and feed-forward. It works at four levels and for the type of feedback given it needs to target the appropriate level of the intended students (Figure 1).

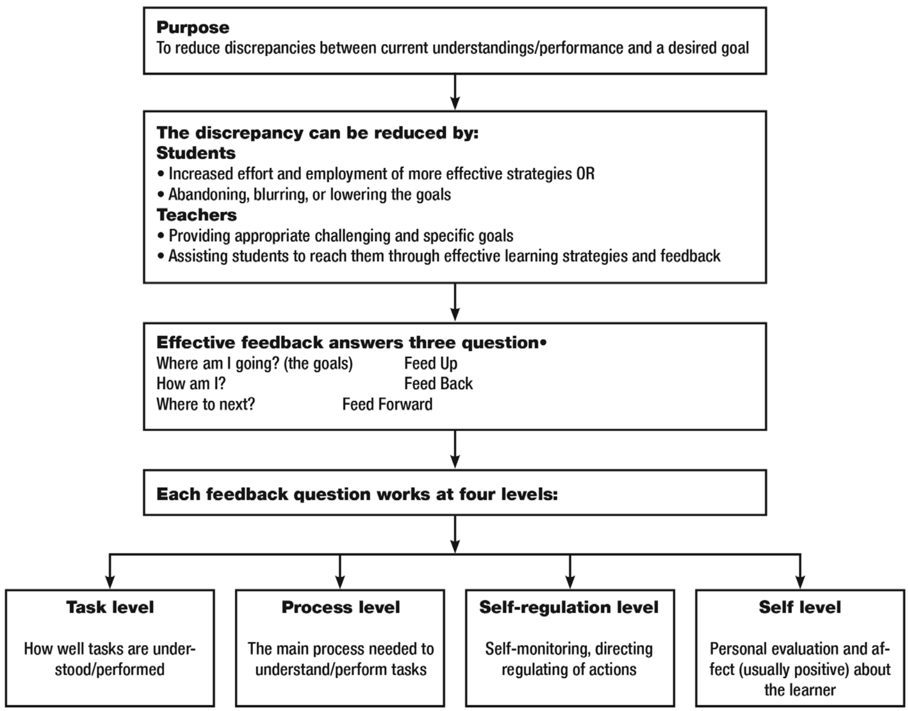

Figure 1. Model of feedback to enhance learning [5]

Feedback in the form of constructive criticism can be both positive and negative, and it describes the students' knowledge at that specific point in time. While both positive and negative feedback can have an effect on learning, it is mainly high-performing students who respond well to negative feedback and low performing students respond better to positive feedback [11]. Forward-looking feedback helps the student in evolving to the better. Regardless, all feedback whether it's about feedback or feedforward, it is important that the information communicated to the students is objective and relevant. For feedback to function effectively in any learning process, it is necessary to both target the task to be conducted and to include information on how the task can be performed more efficiently [2]. A study by Soong, Chan, Cheers and Hu concerning the usefulness of videotaped lectures found that the main reason why students used the recorded lectures was to watch selected parts of the lectures they did not understand [12]. In this study, the possibilities to view and re-view feedback are central aspects, and these are limited to the feedback-questions "Where am I going?" and "How am I?" [5] (Figure 1).

Video recorded feedback can be used, and have been, in other settings such as medical and sports education, where recordings act as an evaluation tool for students reviewing their own actions [13][14]. Peers can take part in a process to find cues for personal development and learning, which in fact enriches learning outcome in sports, as compared to non-peer reviewing [14]. These findings show that peers are important in video recorded feedback, but research on specific settings in higher education including both assessment and video recorded feedback have not been found. Tuck [15] describes the required personal investment demanded by the teachers' giving feedback, and this might also be a key in video recorded feedback. As stated by Rutter [16] it is important not only to show a 'faceless' captured screen but also a picture of the teacher together with audio. This includes a video that provides expressions, gestures and a human voice since it influences learning in a positive manner by stimulating student's interest and communication; this is according to the social-cue hypothesis [16].

The aim of this study is to answer these three questions: can video feedback be used to give students better feedback on their work; is video recorded feedback beneficial for students in helping them understand their work; and how do students' experience feedback given through video in the review of their work?

2 METHOD

To fulfil the aim of the study was a university course chosen based upon several criteria: the course should contain several student projects of which teachers give feedback, the university students should have at least two years fulltime study experience, the course teacher should have experience with and be comfortable using all four types of feedback, and the teacher who gives feedback is to teach all parts of the course and give feedback on all project work. The course Graphic Design and Presentation Technique was chosen as the most appropriate course. Seventeen third-year Industrial Design Engineering programme students at the Luleå University of Technology were recruited to participate in the study and they were informed that their participation and results were to be held confidential.

Each student was given an assignment, in which they presented their work in a narrated PowerPoint recording. All the assignments were uploaded to the teacher's computer, where they were assessed and graded by the teacher. The software recorded the teacher's verbal feedback, the teachers screen showing the PowerPoint video at the same time, and an image of the teacher through a web camera, as in figure 2, as recommended by Rutter [16]. A movie clip with feedback, for each individual assignment, was sent to the subjects, together with the instruction to, first, watch the video with feedback and, thereafter, fill out a questionnaire with 11 questions.

The questionnaire consisted of seven scaled questions and four open questions, where the video feedback was compared to both verbal and written feedback. The students were instructed that their responses were confidential. The questionnaire was developed and shared with and the automated course evaluation system provided by the university. The data collected through questionnaires was analyzed quantitatively with respect to each of the included questions, and qualitatively by weighing every question in the questionnaire to each other in order to find confirmations in student responses to open-ended questions. This was done to find influences that may impact teaching and the teacher's role, statements referring to video recorded feedback was identified.

Figure 2. Example of one of the screen capture made in the study

3 RESULTS

The results in Table 1 show that they personally preferred video feedback to written feedback (*M* = 3.7, *SD* = 0.5) and that 94% (*N* = 17) thought that others would prefer video feedback to written feedback. They also responded that they found video feedback to be very beneficial (*M* = 3.8, *SD* = 0.4). In addition to that, all 17 students stated that they would like be given video feedback for other assignments. The students' detailed responses supported these results in that they explained why they preferred video feedback to written feedback: video feedback gave them a better chance to understand the teacher, since oftentimes written feedback is not fully understood; it's easier to communicate emotions via video; and the feedback was shown to be more specific (detailed) in its content. They also explained that video feedback would be a good option for students with dyslexia.

When considering the option of verbal feedback as opposed to video feedback, the students stated that verbal (face to face) feedback was a more preferable solution (59%), although they stated that they themselves marginally preferred video feedback to verbal (face to face) feedback (*M* = 2.6, *SD* = 0.9), although not a significant difference. They stated that the main benefit to verbal (face to face) feedback was that they could immediately respond with questions to get more specifics and respond to criticism, of which is not immediately possible in both video and written feedback. Although, they did like the possibility of video feedback since they could save the feedback and reflect over it at a later time, especially for specific details, which are often quickly forgotten. In conclusion, video feedback was perceived to be beneficial as a new method for feedback and it was positively accepted by the students and teacher alike.

The teacher's response concerning video feedback vs. written feedback was that it was easier to express oneself and be more specific in pointing out details in the student's work. It took less time to record the video and orally communicate than write it, although the teachers stated that they planned what they would say beforehand. In summary, the teacher felt that they could give better feedback via video as opposed to written feedback. Concerning video feedback and verbal (face to face) feedback the teacher stated that it was easier and more time efficient to use video responses than to plan a meeting and meet the students face to face. It was also stated that it was easier to give a more correct feedback in a video instead of verbal format since the students' immediate reactions were not distracting.

Table 1. Results from the survey

Question	M	SD
Do you prefer video feedback to verbal feedback?	2.6	0.9
Do you prefer video feedback to written feedback?	3.7	0.5
Overall, how beneficial was the video feedback?	3.8	0.4
Do you prefer video feedback to verbal (face-to-face) feedback?	58.8%	
Do you prefer video feedback to written feedback?	94.1%	
Would you want video feedback on other assignments?	100%	

4 DISCUSSION

Since the overall goal of feedback is to stimulate learning [1] and contribute to continued development [4] it is essential to access feedback methods and compare the possibilities. The results showed that both verbal face-to-face and video feedback were preferred over written feedback since it allowed for more specific formative feedback [10] which not only confirmed earlier findings [8] that showed written feedback as being inconclusive in assisting students in their development. The students wanted more information in the communicated feedback, they wanted to read the facial expressions and they wanted to get more specifics in the feedback; i.e. what I did incorrectly, how to improve it and what is required of me in further [5]. If a student can verbally respond to the teacher's feedback in a conversation this would be the most fitting method, that is, if the conversation is recorded. Interaction is a helping factor to student development and video feedback lacks the characteristic of immediate interaction, although it can occur in a delayed rate via e-mail, later conversation, etc. Another advantage of video feedback was the fact that it could be saved and reviewed at a late time when the student was more receptive to other nuances, thoughts or comments included in the information.

Video feedback, although not rated as more helpful than verbal face-to-face feedback it showed greatest potential for improvement in fulfilling the students needs to track their development since it was much easier to follow both thoughts and actions [2] in the video feedback. The feedback given for improvement was recorded and could easily be accessed at any time [12]. As the students responded, the biggest advantage of video feedback is the ability to archive the feedback in a way that is far better than any verbal or written feedback could provide. These finds do agree with earlier literature which state that the key to video feedback is the required personal investment demanded by the teachers' giving feedback [15] and this includes their usage of the three types of feedback: where am I going, how am I, and where to next [5].

An essential part of formative feedback concerns how the student can change the way they think or the way they act in order to achieve the learning outcomes [10] and, presently, written feedback is the most common form of feedback used in higher education. Although, our results show that written feedback was rated as being of lower importance than verbal face-to-face and video feedback, this may show that written feedback does not fulfil the fundamental requirements of feedback. Although, students wanted more information, more detailed information, more specific details that they could correlate to a specific point in their work, as well as, fulfilment of the three levels of feedback, this need does not seem to be met in present written feedback, possibly due to a lack of time for giving feedback. If this is the case how did the feedback differ in the two verbal cases? In general the teacher stated that the time issue was roughly equivalent. Although, in the future the video feedback could become more efficient than the others. As the teacher stated the use of the video recorded feedback did help allocate time better and, over and above all, it helped to give a more correct feedback since the students' reactions were not distracting.

Since the receiver of feedback via video does not have the opportunity to ask questions, it is important that the feedback is clear and precise. Timing of feedback is also important, some delay is essential but depending upon the difficulty of the task and the students need to process their thoughts. Easy tasks do not require processing and thus delaying feedback is unnecessary [5]. In relation to the school year and course schedule, feedback needs to be given before the next session of courses have started so that the students are not too focused upon their coursework to take time to learn from the feedback. Feedback too early and/or too late is not effective since the students are no longer open for the feedback.

5 CONCLUSIONS

The conclusions of this study were positive for the use of video feedback and support further study of video feedback in the higher education since it is an unstudied subject. Firstly, the results showed that video feedback is a viable alternative to verbal face-to-face feedback and it did have several advantages, such as, the feedback could easily be archived and it allowed for a higher level of detail in the feedback. Secondly, video recorded feedback benefited the students in their development process by allowing for a platform there they could compare their development to specific area of their work. Finally, the student's experienced video feedback as positive and welcomed it although they thought that others would prefer face-to-face feedback. Even though they themselves showed that the video feedback they received and verbal feedback they receive were equally acceptable they wanted to receive video feedback in the future.

An enhanced study should be carried out before any concrete conclusions can be made. In future studies it may be interesting to also examine whether students also learn more by getting feedback via video instead of the more conventional methods. So the design of the study needs some improvements to get more viable data.

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Chapter 8

Pedagogical Practice

ORGANIZATIONAL IDENTITY CONSTRUAL THROUGH DESIGN PROCESS

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ABSTRACT
Due to rapid changes in technologies and the market, institutions are not only changing their activities, but also their physical environment. Leadership tends to lead organizations by means of its structure and activities. In this study, due to weakened cultural uniqueness after changing the physical environment, a design school was searching for ways to improve its own personality and creative activities. This research questions how an organizational identity can be enhanced through an internal design process. Case study was needed to exemplify the theory in practice and examine the design process. Participatory observation and archival studies have been used to learn how the self-managed design process can be introduced to lay design process as a consistent discourse.

In this case, the Department of Product Design is challenging students, as design consultants, to cultivate the institute's creative environment and identity. Students are encouraged to involve the stakeholders and to facilitate interactions in their environment through physical items. Throughout the process of trial and error, students have challenged both their personal opinions about the space they occupy as well as those of the other inhabitants. To analyze the findings from the students design process, organizational identity (OI) theory was used. Furthermore, the article analyzes the design process in relation to OI theory in order to study how designers can use concepts of embodied knowledge as an OI construal in the problem space and solution space exploration.

Keywords: Organization identity, embodied cognition, design process.

1 INTRODUCTION

In recent years, higher education (HE) has been exposed to pressures and attempts to change both the content and efficiency of education. In order to move to a "knowledge-based society and economy," [1] the key role of the university is to cultivate capacities required of the flexible, "lifelong" learner, focusing on critical thinking and inquiry-based learning. The fast changing technologies demand different approaches to learning and different models of education that will be enhanced through complementarity of formal, non-formal, and informal learning [2].

Efficiency-wise, there is an attempt to translate commercial practices to HE that are more common for private business sector such as organizational forms, technologies, management practices and values [3]. Over recent years, HE in the UK has developed towards a mass educational model of provision [4]. From 1995 to 2003, HE in the UK experienced a 39% growth in the number of students on full-time and part-time courses [5]. Consequently, for many courses, changes followed in the student–staff ratio. These changes can influence space and routines, as well as merging entities, reorganization of administrative and academic staff, and physical movement of whole departments. These changes demand that organizations be more adaptable to change and, therefore, they need to be robust in renegotiating the meaning of the needs of students and employees. These changes can also, inevitably, lead to confusion about expectations from students and staff as the curriculum is in constant development. Identity refers to the enduring beliefs, values, motives, and experiences that are characteristic of individuals who enact the same professional role [6]. Values and identity are part of the change, and in order to sustain them, continuity is essential for an organization [7]. As design is becoming a tool for intervention in service, businesses, and organizations [8], it becomes relevant to explore what design can do for design schools in the context of volatile changes in demand from both management and students. This article explores how a constant design process can bridge the problem of lack of sustained continuity in values and identity. Leadership tends to see organizational identity (OI) through organizational structure and activities [9]. However, if design thinking is important then design process should be embedded in a consistent discourse in the organization. Within design school campuses there are huge differences in the schools' visual identities and emotional bonding from its users.

2 ORGANIZATIONAL IDENTITY (OI) AND EMBODIED COGNITION

According to Harquail and King [10] "Organizational identity is defined as what is central, distinctive, and enduring of an organization, and is vital to members' efforts to make sense in and of organizations in ways that facilitate effective action." These experiences and their qualities are not only subjective, but also construed, and reside in member's bodies as embodied knowledge (EK) through the process of embodied cognition (EC). They argue that through this process information is interpreted, so that learning happens through a range of sensorimotor physical capacities that are directed toward particular kinds of information. These capacities are bodily–kinaesthetic, visual–spatial, temporal–aural, and emotional. The bodily–kinaesthetic capacity interprets experiences within an organization that engage the movement and stasis of an individual member's body and the interaction with other bodies or physical efforts to transform or construct materials. Visual–spatial capacities are the members' interaction with all elements of the organization's built environment. The temporal–aural capacities concern the members' interpretation of sound, as well as information about the relationships between sounds and events. Finally, a member uses *emotional* capacities to perceive, interpret, and express their own feelings, the feelings of other individuals, and the emotional tenor of a situation or context. This interpretation process happens through "off-line" and "on-line" components of EC. On-line components are the more physical, proximal processes of the body; off-line components shape abstracted knowledge of remote, distal, or even imagined experiences using sensorimotor resources [11]. EK is, therefore, an interpretation of the individual's abstract concepts, after they are incorporated and reflected upon, which is, thus, individual and subjective.

2.1 OI construal and self-construal

"A member identifies with an organization when they experience a concordance between their OI construal through embodied knowledge and their self-construal. In addition, they draw from their construal of the organization's identity a sense of how they might define themselves within the organization [12]." This concordance enables explaining how an individual may employ embodied capacities to assess experience, express an organization's identity or feel attracted to it. These embodied capacities and the member's OI construal may influence the member's personal identity and allow for recognition and claim within the organization; "There is a link between the "self" aspects of identity and the discourses to which they relate [13]." Therefore, OI construed through EC offers an explanation about how individuals may experience pleasure in the activities of construing OI and construing their own self-identity within the organization. According to this, it is not the achievements of an OI construal that members enjoy but the process of construing OI that is ultimately fulfilling for its members [14].

There is a lot of research on OI and identity design; however, there is very little research on the use of a design process within the organization as a tool for constructing or enhancing OI. There is a need to explore how this motivation of construing OI can be harnessed by an organization, and to explain the way in which the production of an organization's practice can influence it. There is also a need to address these processes in the light of design actions and study them as an outcome of the design process around OI construal. Therefore, the research question is: How can an organizational identity be enhanced through an internal design process?

3 METHODS

Case study was needed to exemplify the theory in practice and examine the design process [15]. Participant observation [16] and archival studies have been used to learn how the self-managed design process can be introduced to lay a design process as a consistent discourse. Project participants were interviewed to learn about their personal experiences of taking part in the project [17]. To frame and define the research question, OI theory [10] was used as a theoretical and methodological principle. The EC construal of OI offered the best framework for OI because of its focus on bodily experiences around OI, which is centrally explored in this article. To analyze the findings from the students' design process, the perspective on creative design process' is deployed [18]. This perspective comments on design as a process through the OI by defining what is central, distinctive, and enduring of an organization, and what is vital to its members.

4 THE CASE STUDY OF THE OI OF DEPARTMENT OF PRODUCT DESIGN

The subject of this case study is an attempt from the Department of Product Design Institute at the Oslo and Akershus University College of Applied Sciences, to strengthen and reconstruct its identity after resettlement and reorganization through the process of merging local colleges for optimized administration services and cost reduction. The product design study has its roots back in 1917, and was originally providing teacher education based on design, arts, and crafts. From its foundation to 2003, it was located in an old fortress build to protect against invasions from the Swedish army. Most students lived in student apartments on campus, as the site was in a remote area. The school had good workshops and strong relations to arts and crafts. These conditions certainly led to a unique OI.
The new campus is sited in Norway's largest research area, located on the outskirts of a small city, half an hour from Oslo. Originally, the building was intended for the national telecommunications company's research centre. However, after being partly rebuilt and extended, it now offers high quality classrooms, teaching facilities, and one of Europe's best school workshops. However, the physical buildings and learning spaces suffer from a lack of personality, and significant logistical changes became apparent. Most of the students now live in the capital and even though the institute provides studio space for all the students, social and academic activities after school hours have decreased. The department's curricula has also steadily evolved, and after the introduction of Masters studies the stress was on academic- and research-based education, resulting in materials and crafts losing some of their distinctiveness in OI.

4.1 Student project for identity revival

The initiative to revive OI emerged from different perspectives and motivations within the organization. Facilities and room layouts do not sufficiently support learning forms and activities. Interior, exterior, and physical space do not reflect the core activities of students and staff. There is lack of attitude and motivation among students for activities and exploration. These insights led to the decision to challenge students as design consultants to cultivate the institute's creative environment and identity. The approach was an implementation of a series of student projects named "claiming the space" that will annually deploy problems revolving human-space interaction at the institute. Students were encouraged to involve organization members and facilitate interactions through probes, such as interfaced environments or physical items, and were given the design brief to bring in line institute's identity with its environment. The first student group concluded their work early in 2015. It was a group of four second-year Bachelor students.
The group set out to investigate how the current environment could be made more suitable, indicative, and appropriate for fellow design students. They started using introspection, observations, and a probe to collect information about how other students experience the space at the institute. The group tried to find out how the others related the expression “pride” to the institute through a probe. Some of the insights were: It is a lot of mess here; It doesn't look like a place for product designers from the outside; What does the institute stand for?
The first concepts emerged around observations of student activities and dignifying and refining architectural details through humour and enabling student activity. The numerous ideas were presented at the first meeting with staff, from famous design quotes as stickers on the ceiling to twister game stickers on the floor for a quick exercise after long sitting hours. One approach for both humour and a starting activity was placing a poster in the elevator. The poster heading said "Unpleasant atmosphere in the elevator" and offered a series of questions to enhance interaction between users. This generated many conversations and received positive feedback at the institute. Simultaneously, the group also considered changing the façade as well as the staircase leading to the studios as a separate concept, without any connection with the rest of the efforts.
At this point, the group needed focus and they were discussing what would have the biggest impact on identity and what would be a feasible solution. In this effort, they interviewed their subjects by taking them to different places as they described: "We did not, however, conduct normal sit-down interviews, but took our interviewees for a walk to the different places we wanted to hear about." These interviews led them to think about the process of arrival and departure from the building. The department's working space has two possible entrances. Both visitors and in-house people use one, while only

students and staff use the other (Figure 3). This in-house entrance was found to be one of the most important spaces to change. This was due to it being the building's first daily meeting point for most of the organization's members. Furthermore, this space is currently quite chaotic giving the members a dubious impression. In addition, the group focused on the organization's members' journey, covering the exterior of the building (Figure 1), the entrance area, the interior of the entrance area (Figure 2), followed by the staircases and the elevator. The group made a proposal to the staff: "We advised them to choose the entrance as a focus area, since we think this would have the biggest impact on changing the identity." The concept that was finally presented focused on the entrance, the entry area, the staircase, and the elevator leading to the studios.


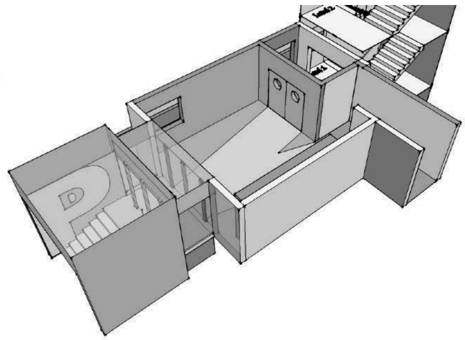


Figure 1. New exterior *Figure 2. New Members' journey* *Figure 3. Old exterior*
Figure 1.-3. all displays the in-house entrance

5 CREATIVE DESIGN PROCESS

According to Dorst and Cross [18] a creative design process is described as a problem-solving activity that relies on the interplay of problem and solution space in which both are developed simultaneously. This study describes how the creative design process constitutes unstable and fixed periods of problem solving. The unstable period is exploratory in which problem and solution spaces are evolving and prone to changes due to discovery and the "clustering of information" [18]. The temporary fixed period happens when a problem–solution pair is framed forming a bridge between problem space and solution space. Therefore, the creative event is defined as the moment of insight in which the "problem framing" [19, 20] takes place.

Therefore, the interplay between the problem and solution space happens through iterative processes of development, refinement, formulation of a problem, ideas for a solution, analysis, synthesis, and evaluation.

5.1 Exploratory process

In the case study, the group was clustering information about the problem space by learning about the existing OI construals from fellow students as subjects. As part of their initial research, students focused on gathering information about different EC capacities through introspection, probe, and observation. The introspection was important for their design process as two of the group members' claimed that the biggest motivation for this project was that it enabled them to actively influence their environment. The introspection allowed them to put into words their own OI construals as they discovered early on that the word "pride" was essential for the problem space. Their next activity was to install a probe to explore how pride was interpreted by the subjects' OI construals. As the problem space was not clearly defined, the group started exploring solutions space, which proved to be useful. They discovered possible solutions and tried to reframe the problem by evaluating the impact of these solutions to OI.

This led them to take their subjects for a walk to places within the school that the subjects related to and then asked them to comment on their experiences. They asked them to interpret what they saw in order to understand crucial aspects of the EK of their subjects. Bodily–kinesthetic, visual–spatial, temporal–aural, and emotional capacities were used as stimuli for the interviews in order to examine off-line and on-line components to learn about EC and describe EK. Based on their research, the students interpreted these insights into the expressions of humour, activity/interaction, and pride. In the description of each design insight, students were justifying their design decisions around the discrepancy between their OI construal and visual–spatial compliance of the institute.

The group defined humour, activity and interaction as central, distinctive, and enduring elements within the organization, and described visual–spatial-, bodily–kinaesthetic- and emotional capacities as being stripped from this quality. They were looking at ways to translate them as desirable EK expressions for the rest of the institute. They experienced a lack of concordance between the subject's OI construal through EK and their self-construal of pride. Subjects were prevented from feeling pride by the lack of stimuli of spatial–visual capacities of EC. This is how subjects defined it through the probe: "You don't feel like you walk into a design school when you walk into the entrance."

5.2 Bridging the solution and problem space

The entrance area is characterized by messiness and an uninspiring interior. The interviews showed that when members of the organization passed this area they felt that their OI was weakened. It did not create the feeling of entering a creative environment. That is the reason why the students found the most distinctive lack of concordance between the EK of pride and their OI construal. While the EK of humour and interaction needed enhancement, the EK of pride needed substantial change. The group managed to create the bridge between the problem space and the solution space by framing the problem of EK through a scenario of arriving and leaving the organization. They believed this experience would have the biggest impact on the change of EC by putting it more in concordance with, or even changing, the construed OI of most of the members. They have chosen this because the entrance is used only for organization members, and leads directly to the workshops and classrooms. By doing this, the construed OI concerning the institute from the inside is expected to reflect the EK of the arriving experience in a better way. The result was affecting both bodily–kinaesthetic and visual–spatial elements with the intention of influencing the emotional EC capacity, and the created situation was accessible only to members allowing them to share a unique experience. The concept covers exterior and interior changes to the building and in-house entrance area.

6 OI DESIGN

OI often seems to be designed by coincidence; however, even if it has been designed with intention it seems to be done without respect for the members' OI construal. There is a value in transferring responsibility and authority for decision making to the organization members. These values are about increased ownership as well as the emergence of the similarities across members' construals. The adaptability of the OI to the volatile changes can, therefore, be seen through an iterative design process that makes an organization aware of members' OI construals and EK. This is important as each member's personal identity and contribution depends on their ability to recognize and claim their role within the organization [13]. The design exploratory phase can make visible member's EK through information clustering techniques, and different interpretations of EC can create discrepancies between an individual's OI construals. This phase also allow members to reflect on the discrepancy between OI construal and their EK, which is difficult to achieve from the outside. The exploration of the problem space can pinpoint the most effective actions for change in OI construal. In this case, it gave new meaning to the existing experience that only members of the organization understood, like the act of arriving at and leaving work.

"Leaders must remember that an organizational change initiated through new rhetoric about OI will need to be substantiated by members in their embodied experience, since abstract constructs do not motivate action as effectively as embodied constructs [21]." The tension between changes in the organizational process and changes in the members' descriptions of their organization's identity happens because organizational routines and social interaction patterns evolve, adapt, and shift over time [22]. The study shows how the design process might be valuable, because the simultaneous analysis and evaluation of problem space and solution space enabled the discovery of what is going to have the biggest impact for members' OI construal. The study implies that organization members own the problem and solution space and therefore are key resource for OI construal. As the study was limited to observation of deployment of design methods on EK it is challenging to discuss to what extent the OI construal can be intentionally created through design process. There is therefore a need for further research on how a design process can influence OI, especially if designers build their design strategy around the OI theory. Accordingly, designers could have a role as educators of a process owned by members of the organization. In contrast to the service designer that would focus on customer experiences, the OI designer would work with bodily–kinaesthetic, visual–spatial, temporal–aural, and emotional touch points, which would bring similarities to members' OI construals.

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FROM NATURES PROTOTYPES TO NATURAL PROTOTYPING

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ABSTRACT
Most educational courses in Product Design and Engineering feature the practice of prototyping. We define prototypes by two conditions. They are both the first model and one which gives rise subsequently to multiple copies (offspring). All around us there are many examples of the offspring of successful prototypes both created by mankind's ingenuity and by the evolutionary processes of nature. This paper is concerned primarily with these evolutionary processes and their possible simulation by designers and engineers. We begin by briefly reviewing the main aspects and practices of conventional prototyping before comparing this with the way in which living systems continually prototype through evolutionary means. This we call biological prototyping. Here we briefly discuss the concept of evolution in nature and also where it is used to express progress in technological systems. The link between conventional and biological prototyping is conceived through developments in biomimicry and the philosophically aligned concept of biophilia. This combination we refer to as *Natural Prototyping* and we then enumerate ten (10) characteristics of natural prototyping. We conclude with some suggestions on how natural prototyping could be incorporated into the curriculum for engineering and product design education.

Keywords: Prototyping, nature, evolution, biomimicry, living machines, biophilia, Goethe.

1 INTRODUCTION

It is now widely acknowledged that research, development and innovation influences economic growth and prosperity [1]. Innovation is the 'critical success factor' for delivering value like market share, long-term growth and profitability. Hence, organisations must endeavour to create the conditions where innovation is considered central to all aspects of their systems, operations and culture, including their future strategies. Design is the fundamental link between creativity and innovation. From an educational perspective, design has been traditionally focused on the "making of stuff" [2]. For instance, product designers make physical and technical artefacts and graphic designers make flyers, brochures and websites. However, in a rapidly changing world, the multi-faceted design landscape has evolved in recent years to better address the social and environmental challenges that now span the disciplines. To some extent, design education has created positive impacts to these challenges through the emergence of new disciplines like interaction, service, transformation and experience design [2]. Moreover, because design is now being viewed as a highly complex activity involving a myriad of actors, many educational design courses are now transforming the way they teach and support their students. For example, in 2009, the Royal Society of the Arts (RSA) released a report identifying six key factors that are all highly relevant to the future development of product design and engineering courses and practices, and none more so than the role and value of prototypes and methods of prototyping [3]. This theoretical paper considers the possible development and interrelationships of conventional and biological prototyping and their manifestation in current biomimicry and living systems design. This results in our postulation of a new branch of prototyping that we refer to as Natural Prototyping. We then suggest how this might be explored by the incorporation as an option, for example, in the curriculum of product design and engineering courses. In parallel, we are currently exploring the idea through a new MA in Ecological Design Thinking at Schumacher College, Devon, UK.

2 CONVENTIONAL PROTOTYPING

Most educational courses in Product Design and Engineering feature the practice of prototyping. Indeed, Warfel (2009) has usefully pointed out that *'prototyping is practice for people who design and make things. It's not simply another tool for your design toolkit - it's a design philosophy. When you prototype, you allow your design, product or service to practice being itself. And as its maker, you learn more about your designs in this way than you ever could in any other way'* [4]. Product prototyping is essentially a generative synthesizing exercise, building up something new from an assembly of parts and ideas. Through incremental step changes in the development process, prototyping activities provide the means for individuals, and/or a group of prototypers, to *'organically and evolutionarily learn'* about their products under development [5], giving them opportunities to [2]:

- *"Experiment/explore ideas"*
- *"Identify problems"*
- *"Understand and communicate a form or structure"*
- *"Overcome the limitations of two dimensional work"*
- *"Support the testing and refinement of ideas, concepts and principles"*
- *"Communicate with others"*
- *"Sell the idea to the client"*

According to Bruce and Baxter (2013) *"the activity of prototyping is usually an intentional, problem-solving activity that culminates in some form of an artefact"* [6]. This artefact is typically known as a 'prototype'. However, for an artefact, process or event to be defined as a prototype, it should fulfil two conditions: 1) It should be the first version of its type; and 2) It should give rise to many copies of itself (we later refer to these as offspring). So, the prototype can be viewed *"as both an activity and an artefact where the artefact or potential artefact is always embedded within the activity"* [6]. As prototyping is now being recognized as an increasingly collaborative activity, it is not surprising that the term has produced many interpretations leading to ambiguity and inconsistencies within the academic literature. From a product design and development perspective, Ulrich and Eppinger (2008) have developed a 2x2 matrix to compare *types* of prototypes along two independent, continuous dimensions [7]. The first dimension represents the extent to which an individual or group of prototypes perceive the prototype to be either 'physical' or 'analytical' (or non-tangible). The second dimension represents the level of fidelity and hence the resolution of the prototype, referred to by the authors as 'comprehensive' or 'focused' prototypes. More specifically, a 'comprehensive' prototype captures most of the attributes (i.e. size, colour, shape, weight, functionality etc.) of a product, thereby making it distinct from all other types of prototypes. Prototypes with these characteristics are most closely associated with *"fully integrated, full-scale version"* of the final product [7]. On the other hand, 'focused' prototypes implement only a few attributes of the product, and are commonly referred to by designers as "looks-like" or "works-like" prototypes [7]. Classifying prototypes along these two dimensions, allows individuals and/or groups of prototypers to view any output from any stage of the prototyping process as a prototype. Alternatively, in human-computer interaction, Houde & Hill (1997) have proposed a classification system to help describe the *purpose* of the prototype rather than its physical characteristics [8]:

- Role relates to questions that address the function of a product from a user perspective.
- Look-and-Feel relates to questions that explore how a user interacts with a product through the stimulation of human senses e.g. how the product looks, feels, sounds, smells etc.
- Implementation corresponds to questions on the technical and engineering methods and components and sub-assemblies needed to perform the product's function.

This simple classification allows designers to locate the focus of their prototyping investigation, enabling them to make trade-offs and better-informed design decisions about the kind of prototypes to build and the tools and techniques to be used. Additionally, Ullman (2003) provides four classes of prototypes based on their *purpose* during different stages within the product development cycle [9]:

- A proof-of-concept prototype is used in the initial stages of the development process to understand customer needs and to establish product design specifications.
- A proof-of-product prototype refines the physical geometries, functional and technical requirements of the product.
- A proof-of-process prototype validates the geometry and the manufacturing process (i.e. pre-production methods and materials).

- Finally, a proof-of-production prototype verifies the entire production process.

Most of what has been discussed above has focused on the aspects and practices of conventional prototyping. However, we believe that prototyping at all systems levels will be a key feature of future "design" activities and will increasingly adopt a living systems approach. So, what now follows is a short discussion on biological prototyping.

3 BIOLOGICAL PROTOTYPING

The biological world is diverse and complex and has been changing for millions of years through the process we know as evolution. Even now, it is speculated that there are many living organisms on our planet, which remain undiscovered, unexplained and unidentified by science. According to Arthur (2009) evolution has two central meanings: 1) the gradual development of something; and 2) the process by which an object is related by ties of common descent [10]. Based on the Darwinian theoretical principles that include natural selection (or the struggle for existence) and the origins of new mutations [11], biological evolution is a subset of biology that helps us to understand the complex interactions between living organisms (i.e. animals, fungi, plants and bacteria) and their environments over successive generations. Darwin understood evolution to be a slow and complex process, writing: "*…Natural selection acts only by taking advantage of slight successive variations; she can never take a great and sudden leap, but must advance by short and sure, though slow steps"* [12]. John Maynard Smith (as cited in Ziman, 2000) argued that for Darwinian evolution to occur, multiple organisms of a single species (commonly known as a population) require the following three properties [13]:

1. *"The entities must be able to multiply and give rise to variation"*
2. *"There must be variation within the population"*
3. *"Some of the variations must be hereditary"*

So, entities must adapt and respond to their current environments to survive, grow, develop and reproduce offspring. The entity must have a slight difference in variation but within certain limits and, any change in population is inherited over successive generations. In its simplest form, Dawkins (1976) captured the meaning of natural selection, describing it as *"the differential survival of entities'*, going on to say *"...entities live and others die but, in order for this selective death to have any impact on the world, an additional condition must be met. Each entity must exist in the form of lots of copies, and at least some of the entities must be potentially capable of surviving – in the form of copies – for a significant period of evolutionary time"* [14]. Classical Darwinism has progressed through the early work of Gregor Mendel and the latest work on epigenetics. At first sight, technological (or conventional) prototyping would appear to have many similarities to biological evolution. After, all, the natural world is always producing new things. To some extent, Ziman (2000) supports this view, pointing out that "*in many respects, both the underlying mechanisms and the broad patterns of technological change are quite reminiscent of those found in biological evolution"* [13]. In light of this, it is important to differentiate between evolution in the context of technological and biological prototyping. In this paper, we view evolution in its narrowest sense when referring to technological prototyping, emphasizing the incremental development of an artefact through small step changes in the process. In other words, prototypes will multiply, give rise to offspring and exist in the form of lots of copies. In biology and genetics, the term *genotype* refers to the heritable characteristics of what is inherited or transferred from one generation to another. Interestingly, Dunn (2005) tentatively suggests that technological artefacts always contain the 'gene of an idea' when moving through the development cycle and could therefore be considered as *genotypes* [15]. So, it is not difficult to appreciate that technological artefacts evolve in similar ways to biological organisms. Furthermore, we know that biological prototyping is a slow and complex process compared to the accelerated evolutionary process of technological prototyping. Indeed, in the natural world, it is difficult to know at times when one prototype ends and the other actually begins. However, one striking feature of biological prototyping is that "*after 3.8*' *billion years of evolution, nature has learned: What works. What is appropriate. What lasts"* [16]. All around us there are many examples of the offspring of successful prototypes both created by mankind's ingenuity and by the evolutionary processes of nature. Biological prototyping has already been utilized, to some extent, by designers/engineers in the design of Living Machines and the study of biomimicry and, it is to this link that we now progress our thinking.

4 LIVING MACHINES, BIOMIMICRY & GOETHE

Prototyping forms an intrinsic part of many design processes, so it should be no surprise that a "living system" version of prototyping should form an important part of ecological design. More than 40 years ago, John and Nancy Todd and Bill McLarney founded the New Alchemy Institute with the main aim of creating ecologically derived human support systems [17]. They pursued the design of systems which had a minimal reliance on fossil fuels and which would operate on a scale accessible to individual families and small groups. This was to be ecological design for sustainable communities. For this, they derived the following basic precepts for ecological design and, by implication, natural prototyping as an integral part of ecological design [18, 19]:

- The Living World is the Matrix for All Design
- Design should Follow, not Oppose, the Laws of Life
- Biological Equity must Determine Design
- Design must Reflect Bioregionality
- Projects should be based on Renewable Energy Sources
- Design should be Sustainable through the Integration of Living Systems
- Design should be Co-Evolutionary with the Natural World
- Building and Design should Help Heal the Planet
- Design should follow a Sacred Ecology

One of the most important developments to come out of their work was the "Living Machine," a biologically based system for the treatment of polluted water and waste-water systems. By using a complete ecosystem approach, the working of the "Living Machine" could effectively use the self-organizing and adaptive capabilities of the organisms to maintain, within limits, the efficiency of the whole system. In other words, each system is co-created and maintained by a collaboration of the human designer and the living organisms. Many "Living Machines" are now operating throughout the world. Janine Benyus [16] would refer to this as biomimicry at the ecosystem level. In this case, it is using an ecosystem to preform directly, and without manipulation, as a human support system. Other examples of biomimicry provide the initial inspiration for a technical idea but, following analyses, only result in an artificial, technical product divorced from its ecosystemic context. Nevertheless, the potential future benefits from biomimicry are immense and well formulated in Benyus's pioneering review [16]. Biophilia is another concept of great significance in this field [20]. When used in association with biomimicry, it produces a morally strong basis for ecological design thinking and for the associated practice of natural prototyping. Johann Wolfgang von Goethe (1749-1832) developed a way of science, which according to Henri Bortoft, embraces and explains a principle of authentic wholeness [21]. This is in sharp contrast to the essential reductionism of modern science. It also provides a method of observation which could prove useful in biomimicry without intervening in the living plant. The method involves four stages of Goethean observation shown below and briefly described and summarized by Wahl (2005) [22]:

- Exact Sense Perception
- Exact Sensorial Fantasy
- Seeing in Beholding
- Being One with the Object

The Goethean method has also been used in the study of ecosystems and landscapes [23] and architecture [24]. Following the brief reviews we have made of conventional and biological prototyping, together with their integration through biomimicry and the potential of using the Goethean method, we suggest a form of prototyping which brings together living and non-living systems in an integral technique we have called Natural Prototyping with the following characteristics.

5 TEN CHARACTERISTICS OF NATURAL PROTOTYPING

1. It takes its source of aesthetic and technical inspiration from the natural world of animals, plants, insects etc.
2. Its original source material always consists of living systems.
3. Its general knowledge comes from the domains of biology and ecology.
4. Its detailed technical knowledge of form and structure comes from the sub-domains of animal and plant physiology, biomechanics, sometimes collectively referred to as biomimicry or biomimetics.

5. Its state of inquiry is always inter/trans-disciplinary.
6. The starting point of inquiries is existing biological/ecological solutions with long evolutionary histories.
7. Its design processes use analytical techniques of scientific and technical reductionism of living systems, the results from which are then processed by technical and engineering synthesis to create artificial, non-living products with little or no evolutionary history.
8. It actively seeks holistic approaches to study the integration of living and non-living systems and the integration of analytical and synthesizing design methods.
9. Its source material and its manipulation are the subject of environmental and ecological ethics.
10. Its philosophical foundations are influenced by ecosophy (from deep ecology) and biophilia.

6 THOUGHTS FOR THE CURRICULUM

This paper is one of a series about our joint research concerned with introducing ecological thinking into the education and practices of product designers. In previous conferences, we have suggested a number of steps that would contribute to an ecology of product innovation and we have also reported on an exploratory experiment to design the content of a suitable Masters programme with the participation of a group of PhD research scholars. In a further attempt to align and integrate product design course and practices with evolutionary processes and living systems, we have used a variation in the well-known concept of prototyping, which occurs in nature and is usually exposed in biomimetic studies. In this paper, we have argued the link between conventional and biological prototyping is conceived through developments in biomimicry and the philosophically aligned concept of biophilia, referring to this combination as *Natural Prototyping.* We conclude with five recommendations that we believe are worth considering in the development of an option/elective in the product design and engineering curriculum:

1. These students interested in this development should be made aware of techno-biological evolution through the expanded application of prototyping. This could involve locating technological and biological prototypes at different systems levels, drawing upon the work of Miller's (1978) general theory of living systems [25].
2. These students should be taught systematic techniques in which they traverse backward and forwards along the art to science continuum. Techniques like "Pulsing and Lensing" reported by Baxter and Bruce (2008) should be encouraged [26].
3. These students should be given an opportunity to acknowledge an "unconscious response to nature" through biophilia. This could be achieved by engaging participants in prototyping activities in other natural environments such as the countryside, woodlands and local parks.
4. Adopting biophilic principles may in turn lead to a "conscious act though biomimicry" and so inspire the creative output of the designer. Therefore, students should be encouraged to study biomimicry, paying particular attention to the technological concepts and innovations that have emerged from design institutions and research organizations. Generating efficient wind power from the study of humpback whales, creating sustainable buildings from the study of termites and learning from the prairies on how to grow sustainable food are some good examples drawn from the literature.
5. Students should be introduced to the basic precepts for ecological design, drawing upon the work of John and Nancy Todd and Bill McLarney.

The research continues through the development of an MA in Ecological Design Thinking at Schumacher College, Devon, UK.

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ORGANIC, BIONICS & BLOB DESIGN - CONCEPTUAL AND METHODOLOGICAL CLARIFICATION

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ABSTRACT
Industrial design is a young field of science that works together with many disciplines, borrows concepts and constructs metaphors for product characterization and phenomenon description. The meaning of the penetrative or constructed concepts is crystallized over time through academic writings and discussions. Organic, Bionics and Blob Design is an example of such a vague concept. Vague concepts create confusion when the concepts are used in academic texts and in course descriptions, which should be understandable across international research and by exchange students. This article discusses the Tripod approach as a possible method to clarify meaning and as an aid to students' development of a technical terminology. The concepts must be used in the same context, in this example the context is Natural Design, and represent different analytical angles on scientific issues. The three concepts of Organic, Bionics and Blob design meet these conditions to form the foundation for a Tripod Approach. The clarifying question in the discussion of meaning will circle around whether Nature Design poses a "paradigm" for industrial design, in which Organic, Bionics and Blob Design separately constitute "sub-paradigms". The citation marks indicate that this study looks at paradigms as practice fields rather than as research programs. The field for this study is set by a design engineer education with courses that cover the three design disciplines.

Keywords: Clarification of concepts, tripod approach, organic design, bionics design, blob design.

1 INTRODUCTION

Industrial design is as a research field so new that it still uses a number of borrowed concepts and metaphors in product characterization and the description of phenomena. Design researchers, heads of design educations and heads of study programs have systematically sought to develop a professional design terminology. Researchers build on previous research as e.g. textile designer Anne Louise Bang in her Ph. D. gets both concepts and the bases for her research grip a Tripod approach from textile artist Kaja Tooming's Ph. D. [1]. Headmaster Bjørn Bråten organized a number of discussion events external partners and students alike with the aim of establishing a commonly accepted terminology which could subsequently be finetuned through use, because concepts can only be incorporated in a field through continuous use [2]. Head of studies Jens Overbye found concepts and the clarification of them in the world of pedagogy, science and art and gathered them in the book 'Clarification of concepts', which he distributed to the students [3]. Theme exhibitions in museums such as 'Bionics, people learns from nature', 'Organic Design in Home Furnishings' and 'Nature Design, From Inspiration to Innovation' all contribute to the clarification and disseminating of the concepts [4] [5] [6]. Authors also do this when they, like Steven Skov Holt and Mara Holt Skov, try to characterize products according to different concepts, as they do with "Blobjects" [7].

Architect Henriette Houth concludes in her study that the purpose of Nature Design is to give life to inanimate things, so that the things can be experienced alive, in the same way as wax figures in Madame Tussauds [8]. Houth uses the term organic design as a collective term for the above four styles, and thus she provides us with an idea of what the term covers. Architect Petra Gruber discusses the meaning of a similar concept on the basis on the concept biomimetics, with the goal of categorising 'architecture of life' and exemplifying how nature has given answers to function problems or constructive problems [9]. The concepts Organic and Blob Design penetrate into industrial design from architecture and Bionics from the natural sciences. The present investigation is limited to the design engineer student’s theory and practice fields, and therefore the concept of Bionics Design is used instead of only Bionics. Biotechnology, Nanotechnology and similar scientific areas like Bionics are based on living nature viewed as a collected field of knowledge, which Bionics Design then draws on. Before the Tripod approach is developed in this study, it is worth to recall Steven Vogel's observation that nature does well in many areas, but do it on the basis of its own merits and that we have other merits. "Nature’s evolved technology represents the only one other than our own to which we have access" [10].

2 TRIPOD APPROACH TO CONCEPTUAL CLARIFICATION

In a young science field, where it not has been possible to draw analogies to previous studies, the researchers ought to begin their study with a methodology and conceptual clarification phase. In that connection, many researchers use a hermeneutical spiral approach to reach a clarification of the concepts applied in the initiating model of reading. An archetypal model of reading is the so-called 'Tripod approach', which is a common term for models that are based on three concepts or three distinctive perspectives on the field of study. The experience gathered after each case study contributes to a nuancing of the terms as well as the reading model. Such a pilot study often reveals a need for a further detailing of the investigative grip. Thus, Anne Louise Bang concludes that the observer's role should be assessed in future studies. In this exemplification of the use of a Tripod approach for conceptual clarification, Nature Design was selected as the context. The concepts Organic, Bionics and Blob Design are all based in nature and can be included in the concept of Natural Design. This concept refers to both "model of nature" and its organizing principles as well as to staging of nature with artificial objects and modification of nature. A For exemplification of conceptual clarification a Tripod Approach is established based on preliminary definitions of Organic, Bionics and Blob Design. The preliminary definition of Organic, Bionics and Blob Design is established in Section 2.2, 2.3 and 2.4 with the associated design processes. The latter contributes to the clarification of the "sub-paradigms" in relation to industrial design. A model of the Tripod approach is shown in Figure 1. It shows the overlap in the use of the concepts, which is the reason for the prevailing confusion of meaning.

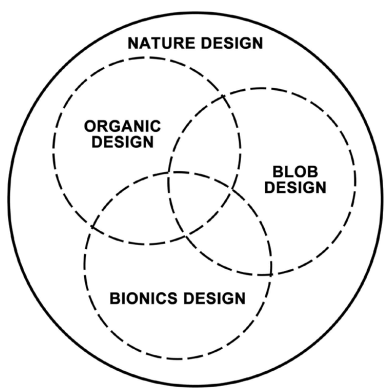

Figure 1. Tripod Approach

Integration of a natural inspired contribution in design process can be derived from Franco Lodato’s Biodesign process, which forms an addition to Design Continuum model [11]. A Biodesign process integration implies according to Lodato the following steps: Input from previous stage - Discovery (standard process for observation of nature), Definition (identifying natural phenomena and principles) Implementation (realizing the biological principle), Evaluation (evaluating and comparing) and – passing on to the next stage. Jørgen Kepler and Marianne Stokholm’s study reveals that the Biodesign process can either be included in the Design Exploration, (that is the initial fact finding: the investigation of, what? why? and how?) or placed between the Alignment stage and the Learning stage [12]. The specific content of the Biodesign process refers to bionics; therefore the specific content of this phase will be discussed in relation to Organic Design in sections 2.2 and in relation to Blob Design in sections 2.4.

2.1 Nature Design

Natural Design as it refers to "the 'model of nature,' with its forms, structures, and organizing principles, does not only inspire the widest range of concepts and design processes, but also can be expressed in a broad spectrum of forms and functions." "Works that do not simply depict or imitate nature but use it as a starting point and reservoir of inspiration for eclectic and innovative responses to the relationship between man and his environment." [6, p.9]

The standard process for observation of nature, which Lodato refers to is, according to Angli Sachs, developed by people like "Maria Sibylla Merian, who with her examination and illustration of the metamorphoses of insects is the founder of entomology; it continues with Carl von Linné, who revolutionized the systematization and classification of nature with his *Systema Naturae*; Johann Wolfgang von Goethe's work as morphologist; Charles Darwin, founder of the evolutionary theory; the explorer and polymath Alexander von Humboldt up to Ernst Haeckel and his influential illustrations of *Radiolarien* (Radiolaria) and *Kunstform der Natur (Art Forms of Nature).* In addition, archiving, cataloguing, and systematization of nature are represented by preparations and models from botanical and zoological collections." [6, p.10] Organic, Bionics and Blob Design all have a Discovery phase that either builds on the observations of others or theirs methods of observation. Within Organic Design exceptions occur where the designers have put an artistic interpretation on the observed. Whether Lodato's Biodesign phases Definition and Implementation have a different approach than the ones in Organic Design and Blob design will be discussed in Section 2.2 and 2.4 respectively.

2.2 Organic Design

On October 1, 1940 the Museum of Modern Art in New York arranged the competition 'Organic Design in Home Furnishings'. After the competition, Elliot F. Noyes tried to define the concept of Organic Design with this: "A design may be called organic when there is an harmonious organization of the parts within the whole, according to structure, material, and purpose. Within this definition there can be no vain ornamentation or superfluity, but the part of beauty is none the less great - in ideal choice of material, in visual refinement, and in the rational elegance of things intended for use." [5, inside of cover] In order to understand the Organic Design process and its purpose, it is necessary to know that one purpose of the competition was to bring forth the sweeping, feather light lines that appear in nature and that are tied to the human soma. This to break with the strict geometric forms that characterized functionalism, which had just been modern. According to Sachs, the inspiration to the competition was Alvar Aalto's Finnish Pavilion at the New York World Fair (1938-39), which Aalto transformed and turned into an 'organic exhibition'. Aalto's Savoy vase has since become an icon of Organic Design. Eskimo women's leather pants were the model for this vase [13]. Noyes also highlighted about the exhibition that industrial design appeared to be conscious as an art form, with their use of the aesthetic anguish that constituted the apparatus of industry production. And he noted the designers' courage to take up the challenge of experimenting with new solutions, just like Charles Eames and Eero Saarinen did when they managed to create double curved plywood chairs. Thus, Organic Design combined the search for constructive and functional solutions with a decoding of the leading feature and textures from nature to give a product a particular expression or symbolic value, as in Eero Aario's Pony Chair. For this approach design engineers use the concept "tectonics"[1] [14].

The hypothesis that about the Biodesign phases contains the same for Organic Design as for Bionics Design is true for the Discovery phase, because artistic abstractions are generally based on approximations to mathematical curves or formula, at least for industrial designers who use CAD programs in modelling [14]. The model for the Pony Chair, Aario made in Styrofoam and clay; but it retrieves only the main features from a pony and the resilience of musculature is absent. The Definition phase is also adequate for Organic Design, because the preliminary research before the Biodesign stage target the Definition phase towards the clarifying of a leading feature that can unite the tectonic solutions with a whole or ensure that an aesthetic statement is realized in the form. The Implementation phase materializes the leading feature or integrates the aesthetic statements in the

[1] "Tectonic becomes the art of joinings: Art" here is to"- be understood as encompassing tekne and therefore indicates tectonic as assemblage not only of building parts but also of objects….. as soon as an aesthetic perspective - and not a goal of utility - is defined that specifies the work and production of the tekton, then the analysis consigns the term "tectonic" to an aesthetic judgement".

form. The Evaluation phase includes the designer's artistic ambitions, and like the Eames and Saarinen, an evaluation of their own experimental capacity.
In the courses in Organic Design for design engineers, the students are challenged on their abstraction abilities and they must draw either on their math and/or Cad experience as well as on their sense of space. The decoding of the leading feature is based on the recording of the leading curve (parts) and the sectioning of natural objects perpendicular to the part. Subsequently, the decoded object is transformed into a product, while retaining the feeling of life or the rage of the elements.

2.3 Bionics Design

The introduction to the exhibition "Bionics" it said: "The word 'bionics' was first used in 1958 by Major Jack Steele, an engineer in the US Air Force, to describe making copies of nature and finding ideas in nature. Although the word is not very old, there is no doubt that humans have observed nature to find solutions to technical and design problems for thousands for years."[4, p.5] and "In the last 10-20 years, centres have turn up all over the world where they work on decoding nature's recipes for materials and structures. The centres house eight interdisciplinary environments where biologists, engineers, doctors, physicists and chemists work together." [4, p.6] From this the conclusions can be drawn that the design problems involved are those concerning the natural science fields. And that the methodical approach is attached to each subject field, although many systematics in natural sciences are common or as Lodato put it: "use standard process for observation of nature". The many examples of Bionics reveal that this science field only draws on biology and zoology, and not on nature as a whole. The word Bionics is possibly a contraction of 'bion' that means 'unit of life' and the suffix -ic, means 'like'. Bionics Design deals, according to Holt & Skov, with the technical transformation and application of structures, procedures and development principles of biological systems. This, by its very nature, makes it an interdisciplinary task that combines biology and zoology with engineering, architecture and mathematics [7]. A review of Holt & Skov's many design examples reveal that the used constructional and functional principles do not have reference to nature as opposed to architecture examples. The main feature of Otto dental floss may make references to the human body but its combined holding and cutting tool does not, so this product will be placed in between the Organic Design and Blob Design field in figure 1. The same is the case with Folpo's hand mixer, just to give a few examples. On the other hand, Philippe Starck's WW Stool uses a design principle where the branch splits into three and may be placed in between the Bionics and Organic Design. And Velcro with its working principle from Linden burrs belongs in the Bionics field.
Our course in Bionics Design challenges the student's systematics and innovative abilities. It consists of a problem-based project which must be answered by creating a product that either uses the observed bio-/zoological principles of construction and function or identifies a bio-/zoological principle of construction or function and then finding a design problem which can be solved using this principle [12].
The word Biomimicry shows up if you do a search on Bionics and largely the two concepts reference the same examples. The concept is said to be constructed by Otto Herbert Schmitt as a contraction of 'bios' and 'minieses' meaning, 'life' and 'imitate', respectively. A search on university design courses in Biomimicry shows that they are generally described as having focusing on innovation, in preparation for sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies as a basis for the innovation. As Sustainability matters are not the focus of our Bionics course or present paper, Biomimicry is considered a paradigm which contains bionics.

2.4 Blob Design

Blob Design deals with the design of objects defined by their quintessential fluidity with double curved surfaces, with the exception of the supporting surfaces, which may be plane. Objects that represent buildings are also referred to as "Fluid Architecture" because of the characteristic flowing goopy, drippy, swoopy, seamless, merging, converging, bulging, morphing, overlapping shapes and the absence of sharp edges [7]. Gunnar Aagaard Andersen's 'Portrait of My Mother's Chesterfield' from 1964 can be said to constitute a design icon for the concept Holt & Skov constructed as a contraction of "blobby" and "object" to blobject.
As a paradigm Blob Design belongs in Nature Design because the original inspiration came from corroded beach rocks, the kidney, softbodied animals or organisms and amoeboid cells that appeal with their cuddly, playful and body friendly appearance as shown in Marc Newson's Lockheed Lounge

from 1986-88. The paradigm is developed not until the early 1990s with the spread of 3D design computer programs that are able to describe the geometry of the curved surfaces accurately and produce programs and production equipment, which can handle the extreme individualization of the components [16]. Blob Design remains extremely challenging to design engineers, computer scientists and industry technology development although with the help of 3D printer industrial production is well on the way. The challenge for computer scientists is to create user-friendly programs that can generate the 'blob' shapes that architects and designers request. A 'blob' is a collection of data that control a flowing mass – a flux. The designers are challenged when controlling the movement patterns of the flux and setting the limits for these.

Today the Discovery and Definition phases in Blob Design have much more focus on investigating and understanding opportunities in existing generative computer programs and how these experiments should be decoded than on how studies of nature can help develop new program facilities. The designers have also more focus on using new technologies and manufacturing methods than on contributing to the development of new technologies through their experiments. This concerns the designers who create new products. Contrary to this, Lodato's Biodesign process is useful for designers who work together with computer scientists to create new contributions to computer programs that can generate natural flow or movement patterns. During our course in digital design, the design engineering students tried their hand at 3D flux computer programs alongside architecture engineering students. They tried to create ergonomic furniture, which seems to be as big a challenge as creating a climate-optimized building. Many of the blobjects the designers created were of such a small size and complexity that they could be modelled manually, but as a teaching discipline, Blob Design must differentiate itself from Organic Design. It is precisely the 3D generative computer programs that generate flux that make Blob Design interesting. The discipline also challenged the design engineers' sensibility in a different way than Organic Design, where they have the support of the resilience of musculature or skeletal structures.

3 TRIPOD APPROACH TO METHODICAL CLARIFICATION

Does Tripod approach in design engineering programs constitute a more appropriate method of conceptual clarification and development of a technical language than those mentioned in the introduction? It has not been possible to test whether Overbye's methods are a better alternative for our education, because we do not have a corresponding 'Clarification of concepts'. However, Overbye's has been tested in a single course, where we found the shortage of engineering terminology to be too big, but the method could be used as a starting point for developing one. For the architectural engineering students that participated in the course, the architect Søren Koch's 'Technical terms from the traditional construction' was a good supplement [17]. The program has no tradition for initiatives such as Bråten's with seminars where students discuss multidisciplinary matters and concepts from penetrative research fields, for example from scent and sound design and in collaboration with hospitals and the home care or nursing sector.

The testing of the Tripod approach which combined conceptual clarification and analysis methods was undertaken in connection with the students' preparation of scientific papers. In that connection, the Tripod approach has been introduced as a possible alternative approach for students who chose a theme for their paper which had not previously been addressed in the context of industrial design. The surrounding space, availability of equipment, workshop facilities or access to materials and their impact on the creative process are examples of matters treated by this method. In connection with the preparation of papers, the students participated in seminars, where they were eager to contribute with their observations of diverging concepts. The seminars served as an eye-opener when it comes to obscure use of concepts and the subsequent presentations by the students have not exactly clarified the concepts, but they contributed with qualified suggestions as to the definition of the concepts. The previous Tripod based on Organic, Bionics and Blob Design - without Biodesign process considerations, - was tested as an analytical method based on the assumption that the students would get a clear understanding of the concepts through the courses. Unfortunately, the assumption proved to be false, which is the reason for this attempt to establish a foundation for future clarification.

In previous experiments with the Tripod approach, it worked well when the concepts were associated with a single research field, although the related paradigm was unknown to the field of design.

An example of this is how scents have a memory provoking effect on the innovation process; an approach based on both a multi-sensory and a memory concept, both from one incorporate research program. The situation was not as simple for the concepts Organic, Bionics and Blob Design, because they are both emerging in the design area and in their original areas. Blob Design is a new paradigm and a practice in relation to new technology and production equipment. The analysis is complicate by the fact that the artist, the architect and the designer affect the development of the common computer programs and they all contribute with blobjects.

4 CONCLUSION OG FUTURE WORKS

Organic, Bionics and Blob Design represent all sub-paradigms in Nature Design. Organic Design in a wide sense draws its aesthetic statements from nature. Bionics Design takes its point of departure in living nature and limits its activities to the natural science fields. Blob Design has only an indirect link to Nature Design with regard to product design, but draws directly on nature's processes and principles for the development of computer programs which generate mass flow. The Blob Design aesthetic statements reflect also flowing cultures detached from nature. Lodato Biodesign process covers Organic Design when the process input is aimed at defining the leading feature. The Biodesign process description covers Blob Design for the design engineers involved in the development of computer programs, but not for the others. From what has been found, it seems probable that Tripod can only be used as an approach to conceptual clarification and analysis when the concepts belong to the same well-established paradigm. This paper can be seen as input to a test of Tripod with Organic, Bionics and Design Blob as basis.

In a course about the development of papers, the students studied subjects that have not previously been the subject for design research and therefore the students needed a proper methodological approach. In this connection, the Tripod approach also appeared suitable as an initiating reading model, based on the first guess at characteristic perspectives of the study field.

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BOUNDARY OBJECTS AS MEANS FOR KNOWLEDGE GENERATION IN DESIGN EDUCATION

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ABSTRACT
Design spans a range of disciplines and stakeholders and communication between them can be hampered by various misunderstandings. Moreover, professional knowledge in design and architecture is often difficult to mediate because it is tacit, embedded in practice and dependent on situated contexts. Boundary objects (BOs) have the potential to connect diverging views of professionals and stakeholders by providing a common ground for discussion. This paper discusses the concept of boundary objects and analyses a workshop with university teachers from design and architecture, where the double diamond model (DDM) was used as BO. The results of this workshop illustrate that BOs facilitate understanding of design concepts and processes, and their use create an arena for professional and social interaction. Further, BOs might be a good tool for design curriculum however they come with different challenges. The results of the workshop are presented, and BOs for design education are evaluated. Finally, the paper will outline possibilities and challenges to include BOs in design communication and curricula.

Keywords: Communication, boundary objects, communities of practice, BOs in design teaching.

1 INTRODUCTION

In design and architecture, areas of research, practice and education often struggle to generate mutual understanding [1] due to different agendas and needs. Since objects in the widest sense (things, articles, concepts, toolkits, models) provides a common topic of interest for these areas, the concept and methodology of boundary objects was found to be a suitable means to stimulate discussion and understanding. Boundary objects facilitate the coordination of work because they can be interpreted in a tightly focused way by specialists, while being simultaneously readable by generalists [2]. They might also create an arena for social interaction: the design process can be shared, at different points in time, by different members of a community.

This article discusses how boundary objects were applied in a workshop with design and architecture teachers from different colleges in Nepal. The three hours boundary object workshop took place in the Himalaya College of Engineering in Kathmandu in December 2014. It comprised twenty participants and three facilitators and had a twofold goal: To explore whether boundary objects can contribute to improved communication between different design areas and to discuss whether and how this kind of workshop can be applied for design education. The hypothesis was that exploring types of objects and how they are regarded and interpreted may facilitate communication and knowledge sharing. The author has conducted two boundary object workshops earlier, in Oslo and Chiba 2013 [3] lessons learned from those have been taken into account when conducting the boundary object workshop in Kathmandu.

2 THE CONCEPT OF BOUNDARY OBJECTS

2.1 Theory

A boundary objects can be described as "...an object that lives in several social worlds and which has different identities in each" [4]. Kimble et al points to an additional feature: "Boundary objects are artefacts that link sets of diverse interests; they are the physical or virtual entities that allow groups to coalesce and form a stable, if transitory, working relationships" [5].

One way of categorizing BOs are: repositories, ideal types, coincident boundaries and standardized forms [4]. Carlile gives characteristics of effective boundary objects:

- “An effective boundary object at a semantic boundary provides a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary.
- At a pragmatic level boundary an effective boundary object facilitates a process where individuals can jointly transform their knowledge” [6].

Boundary objects can be made part of communities of practices as Kimble explains: “When different groups collaborate on a common task, some form of local agreement is necessary for the work to proceed. As the work progresses these temporary local arrangements are subject to negotiation and renegotiation; new understandings are forged, new ideas generated and new accommodations made as the groups interact with each other”[5]. Boundary objects are means of a common discourse among disciplines and models represent one category of BOs [5]. The advantage of BOs as mediators between design areas is that BOs are flexible and plastic enough to represent specific needs and constraints of one area, while their use allows developing and maintaining coherence across intersecting areas. To test this hypothesis in practice, we used a generic model for a BO workshop, the double-diamond model (DDM) being the BO. The DDM is familiar to both architects and designers, simultaneously allowing diverging views and interpretations. It consists of divergence and convergence stages, which are related to the iterative design steps of observation, ideation, prototyping, and testing. These stages can also be related to the iterative design steps of observation, ideation, prototyping, and testing. The double-diamond model was used because most teachers can identify standard teaching with the stages of the model.

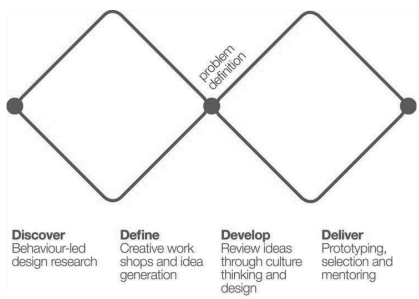

Figure 1. Double diamond model [7]

The double-diamond model was considered an appropriate BO for the workshop, because many design and architecture teachers can relate standard teaching process to the stages of the model. The goal of the workshop was a) to test the BO character of the double-diamond model, and b) to test the value of boundary objects as mediator in deign and architecture education. For the workshop, four sets of 25 similar photo cards were designed and subsumed under three main design notions: Problem-solving, Semantic interpretation and Practitioner reflection. The task of the boundary object workshop participants was to relate 3-4 cards out of 25 for each group to the stages in the DDM. Further, they had to reflect on the cards’ selection and on the decision-making process. Finally, they had to reply to a questionnaire and evaluate the DDM’s usability as a BO, the workshop conduction, and the overall use of boundary objects for communication among professionals and for design education.

The design notions above are borrowed from Simon, Schön and Krippendorff’s concepts [8]. The problem-solving notion refers to Simon’s assertion 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”. 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. Simon’s approach is cognitive and instrumental and the cards were design with rational decision-making, order, structure and traditional approaches in mind.

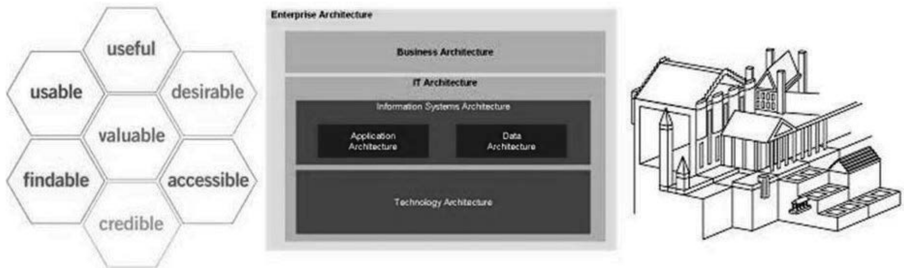

Figure 2. Problem-solving notion cards

Semantic interpretation is a term which characterizes Krippendorff's concept, which puts a lot of emphasis on what artefacts mean to the people affected by them. For him, design "…brings forth what would not come naturally (...); proposes realizable artefacts 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." These cards were design relating to expressions, cultural understanding and diversity of explanation.

Figure 3. Semantic interpretation cards

Practitioner reflection: Donald Schön's crucial argument is that 'reflection-in-action' can contribute to a new understanding of the problem and change a situation. By becoming aware of former tacit frames, the practitioner sees new links and relationships to the situation. Schön asserts that the cultivation of the capacity to reflect in action as well as the ability to engage in a process of continuous learning is defining professional practice [9]. The practitioner reflection cards were design with heuristics, individual development and group processes.

Figure 4. Practitioner reflection cards

2.2 Organization of the workshop

The workshop duration was three hours in total, 20 teachers from architecture and design for undergraduate and graduate studies participated. The participants got information in form of articles on boundary objects by forehand but this was alas not evenly distributed. The following schedule and content was used:

1. **Introduction (20 min):**
   Explaining boundary objects, their role and relevance for cooperation and the goal of the workshop: to explore whether boundary objects can contribute to improved communication between design professionals as well as to education.
2. **Description of task (10 min):**
   The participants were divided into groups divided into groups of 5 persons. Each group got a set of 25 cards. They had to choose representative pictures related to the DDM phases, 3-4 for each phase and discuss in the group how the pictures represent their understanding of the design process. The cards had to be presented in plenum. The following questions were asked as starting guidelines:
   - In which phase does card represent and relate to the DDM?
   - What are the qualities/aspects it represents?
   - Which card does not fit at all to the DDM?
3. **Exchange (60 min):**
   The groups chose representative pictures related to the DDM phases, and discussed how the pictures represent their understanding of the design process related to the questions above. The group also wrote notes on:
   - how the choices were made
   - how negotiations took place
   - what pictures were finally selected
   - why the selected pictures were presented as important representation of this DDM phase.
4. **Presentations (60 min/10 min each)**: Each group presented their DDM cards by addressing the questions from 2 and 3.
5. **Common discussion (30 min):** Discussion of the relevance of the DDM and BOs with the groups attending the workshop relating to their importance for professional communication and as possible tool for students. At the end of the workshop the participants got a questionnaire which all participants filled in.

Figure 4. Selection of cards and process

1. Did you have any former information on the BO concept?

No former information	I have heard about it	I know the concept

2. Was the information you got before the workshop sufficient?

Too little information	Acceptable	Sufficient

3. How would you evaluate the workshop's organization?

Poor	Acceptable	Good

4. Were the aims of the workshop clear?

No	Acceptable	Clear

5. What would you recommend for improving the workshop?

6. How do you evaluate the communication in your group?

Poor	Acceptable	Good

7. Do you feel that BOs facilitate communication between experts?

Poorly	Average	Strongly

8. Do you feel that BOs facilitate understanding between experts?

No	Partly	Yes

9. What would you recommend for improving communication and understanding in the group?

10. Do you think the BO concept is useful for students?

No	Partly	Yes

11. How far is the BO concept useful for your teaching?

Not useful	Partly useful	Very useful

12. Do you feel it is worth to put more efforts applying BOs for education? If yes, why? If not, why not?

Figure 5. Questionnaire for BO workshop Kathmandu

3 RESULTS

95% of the workshop participants had no former knowledge of BOs and 53 % would like to have more and detailed information before the workshops starts. One participant also suggested that the DDM model should be discussed more thoroughly by forehand. Another said that the selection of the BO should be decided by the participants and that the DDM was too 'design-oriented'. The idea of the BO, besides the DDM being appropriate or not, was that BOs facilitate common understanding and professional interaction (63% average, 37% strongly). As to the choice of cards based on notions, the problem solving was slightly dominating as choice in the groups, followed by the reflective practice and the semantic notion. One participant emphasized that "…BOs give the opportunity to see things in a different way and allow presenting a concept in a logical way." Communication within the groups was considered good (84%, acceptable 16%); however, Nepalis are thought of as shy in expressing controversial views in a group, which can hamper a lively discussion: "…they don't express themselves." Some required a more structured discussion: "People can have their say one after another on each card and afterwards the group makes a common decision." And: "Shys should be given the possibility to express themselves by the dominant ones." The participants see the usability for a BOs workshop for students especially in developing group work: "… it develop habits to work in groups and take things analytically". They also mentioned that the BOs might contribute to increase creativity among the students: "The process of BO would be useful to help students to solve their assignments in a creative way", and that the students will be motivated to take active part in the education. The participants found the cards useful for their own teaching (32% partly, 68% very useful) and for explaining assignments and students projects. Finally, one participant suggested that physical models would be even better than cards, which was supported in the discussion and led to the plan to arrange a hands-on boundary workshop at the Himalaya College of Engineering in May 2015.

4 CONCLUSION

Findings from the workshop, the answers from the participants' questionnaire and a brief literature review indicate that professional knowledge is embedded across functional boundaries and that sharing knowledge is possible but also that it comes with some challenges [5]. For a BO workshop it seems essential to distribute detailed information about the process and the background before the workshop starts to create a common ground and basis for discussion. This seems even more important when organizing BO workshops for students, who have less conceptual knowledge and practical experience.

One can also chose models that are closer to the participants daily teaching practice in the studio than the DDM, or let them suggest ideas for BOs. This has to be tested out in the future.

It is likely that BOs can bridge gaps between different concepts, views and practices [6] and work as channels through which distinct individuals and groups can communicate and collaborate [5]. However, they are also oversimplifications of rather complex concepts and relationships. In a social and discursive context, facilitators have to be aware of group hierarchies and discourse development, possibility introducing routines to make all voices heard. One should also consider if it facilitates the discussion if participants/students are provided with /or design themselves tangible objects – also this has to be tested. Further, it can be questioned whether boundary objects is the right term for the DDM and the cards used in this workshop. Lee states e.g.: "I would argue that objects that are used and adjusted through simultaneous group interaction are not a new type of boundary object, rather, while similar and related, they are not actually boundary objects at all [10]. Despite these criticisms, BOs contribute to facilitate co-activities and to establish communities of practices, as the three workshops conducted so far have shown [3]. The choice of the BO and the practical arrangements of the workshops are improvable. From my point of view, BOs get their significance through being a designerly way of knowledge generation by combining a visual and an analytic way of understanding, which is beneficial for design students, who often struggle with theory comprehension.

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Chapter 9

Social Issues

CRITICAL DESIGN FOR DISCUSSION ABOUT PUBLIC SPACE

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ABSTRACT
This research focuses on Critical Design and the use of provocative design objects to create discussion about public space. The project sets out to develop a design approach and a critical design method for making conceptual design proposals and objects that encourage meaningful reflection on design and public space. The outcome is the development of a method and a set of tools to understand and try to create a language of critical design. The results have some common features and thematic categories that will be developed further in the project for the use of design as tools for various critiques in public space. By visualizing possible futures in public space and redefining the functions and conventions, the further research and findings will discuss how critical design can be structured and how it can contribute to design for public space. The intention of the research conducted and the following project was to design a collection of several conceptual design proposals that shift focus from design and object, to the idea and concept, challenging ideas, traditions and the users. The experiments were not for the object to be a set of practical proposals, but to open for conversations among the collaborators and viewers about the value that they might embody. The imaginative encounters staged by the objects reflect the mission to provoke a dialogue of the role of objects and the state of design and objects of this time by challenging the observer to participate in constructing their meaning, with their questions, interpretations and criticism becoming part of its meaning,

Keywords: Critical design, critical artefact methodology, estrangement, poetics, play, public space, product design.

1 INTRODUCTION: ETHICS, OR AESTHETICS?

´In an age of mass production where everything must be planned and designed, design has become a powerful tool which with man shapes his environments, demanding a high social and moral responsibility from the designer.´ [1]
Design studios have grown into client-targeted companies and are fully integrated in the industrial system. Some young and independent designers are questioning the developments in our society and their own motives to produce work. They are interested in looking into the ideas and concepts behind the design and to see how things can have meaning beyond just being stylistic idioms. They have encountered a problem that design has been too focused on being prepared for a production system and focused on stereotype users and that it has taken little account of human relationships, immaterial values, dreams and emotional needs.
The boundaries between creative fields are disappearing and the purpose of design is constantly changing. Many designers are distancing themselves from simply creating beautiful objects aimed for mass-production. They are engaged with creating a more personalized language which enables them to create more participative critical frameworks. Design does not only have to be about solving problems, and not necessary a way of promoting and creating objects. It can also be about finding problems [2, 3]. Instead of serving the industry, it can serve society. Instead of making people buy, it can make people think.

1.1 Critical Design

This article presents an introduction to a critical design method, presenting historical and contemporary perspectives within critical design, and the use of critical design for discussion about public space. In the recent years a movement has developed that focuses on design as a medium for critique [2]. Critique of design has been almost non-existent in Norway and in the Norwegian media.

A debate article in Norway's largest newspaper ´Aftenposten´ earlier this year, called *En bedre Designkritikk* [4] questions why the good academic design foundation lacks of design criticism, while there are good standards for criticism within fields such as art, music and literature. The criticism in the article focuses mainly on and is based on the problems outside design itself and on the market based organization. The following research takes a different stance and addresses the design professions own challenges and limits by reconsidering the principles behind design, and within design philosophy itself. The term Critical Design was first used in Anthony Dunn's´ book Hertzian Tales [3] and later in Design Noir [5]. Dunne and Raby provided this summary of critical design in an interview about their *Designing Critical Design* exhibition [6, 7]:

> What is Critical design? Critical Design uses speculative design proposals to challenge narrow assumptions, preconceptions and givens about the role products play in everyday life. It is more of an attitude than anything else, a position rather than a method. There are many people doing this who have never heard of the term critical design and who have their own way of describing what they do. Naming it Critical Design is simply a useful way of making this activity more visible and subject to discussion and debate.
> What is it for? Mainly to make us think. But also raising awareness, exposing assumptions, provoking actions, sparkling debate, even entertaining in an intellectual sort of way, like literature or film. [6]

Critical design, popularized by Dunne and Raby, uses design artefacts as an embodied critique or commentary on consumer culture. Both the designed artefact (and the subsequent use) and the process of designing such an artefact causes reflections on existing values, mores and practices in a culture. With the influence of e.g. the Dutch design company and the movement Droog Design [8], which was established in 1993, there are areas of design that work more on an art level. Objects created to address issues, explore ideas and express thoughts that have little to do with commercial applications. This critical and questioning aspect of what has come to be called critical design, is appropriated from what is a more an artistic approach. It welcomes pauses and stops within the flood of visual consumption and asks interesting questions about the relationship between a particular type of design and art [8].
Since the 1920s it was believed that the Bauhaus formula of ´form follows function´ required a minimalistic language of form suited to the industrial age. At the end of the 20th century, the slogan for many designers changed into ´form follows concept´. Design as critique builds on attitudes of Italian Radical Design of the 1970s who were critical of social values and design ideologies [6]. Dunne describes critical design as being related to critical theories quoting this passage from Raymond Guess: ´Critical theories aim at emancipation and enlightenment, at making agents aware of hidden coercion and putting them in a position to determine where their true interest lie.´ [9]

2 METHOD

2.1 Critical Artefact Methodology

The main method intended to use for this study is a critical artefact methodology by Simon John Bowen [10]. Through research into and practical experience of this method, the aim is to utilize similar techniques and tactics to develop a critical design method suitable for other contexts, such as product design education at tertiary level or higher and also for urban planning. The intention is to present this method and its underlying methodology and practical exercises in a workshop with stakeholders related to the project. These workshops are to generate discussion on how designers and stakeholders might employ similar tactics to their own practice, and how to generate debate about the use of critical design for public space. The intended result of the findings of the research and study was to develop a series of tools and models that will enable me to develop a critical design methodology.

2.2 Case study: Kongsvinger Town Square.

The suggested development for applying the critical artefact methodology consisted of several stages. The intention of following case study [11] is to use the critical artefact methodology [10] to gain insight to the applications of its principles for design practice and to see how it might be deployed in a collaborative urban planning project with Kongsvinger municipality and stakeholders related to the development of the town square. Kongsvinger is a town and a municipality in Hedmark County, Norway. The collaborative partners and resource persons were a cross disciplinary team consisting of approximately ten people, who all were working on the development of the local town hall square. The team consisted of city-planners, landscape architects, a traffic team leader and an advisor for managing projects between public administration and social entrepreneurs. Kongsvinger has a town square located in the heart of the city, which the municipality wanted to upgrade both aesthetically and to create more activity in the space. The project was in an early stage and initial explorations had been done by the stakeholders by conducting observations and discussions in the team, and initial idea generation with drawings by the landscape architects in the team. Town planning is important to understanding the idea ´think globally, act locally´. The management and development of urban space and objects within this space, highly impacts the surrounding environment. When planning on changing the dynamics of a space and the objects in this space, the focus of the critical design work was to develop (social) structures that facilitate individuals (stakeholders) in critiquing and improving themselves and in the society in which they function. As a designer, it was exciting to get the opportunity to serve a local site, the town square, by conducting critical design workshops with stakeholders and local citizens. The researchers role in the present case was not simply as a designer or even a critical designer, but as a designer as author/change agent [2, 6].

The learning sciences and product design community have participated in developing countless artefacts, technological objects, tools and principles for designing them, but less commonly in this design work is a critical agenda. Borrowing on the language used in ethnography, a critical agenda is one that calls into question and potentially disrupt existing practices structures; it communicates a commitment that the work reflects a critique on the status quo, even exposing inequitable power structures, resource allotment, divisions of labour, or dis-empowerment [10]. The idea is that a critical curriculum carries within it a disruptive agenda that can be implemented by transforming the curriculum and the contexts in which the designs are being realized.

2.3 Discussion workshops and focus group interviews

The first stage of the critical design work consisted of a series of one-hour discussion workshops with the stakeholders. With the intention of investigating new possibilities for the town square, and in this case the use of critical design for public space, the initial exploration also aimed for using qualitative interviews [11] within a focus group of potential users to understand their goals and needs. ´Note that these interviews at this stage are not focused on functionality and design, the goal is to understand the needs and challenges presented by a particular situation.´ [12]

The ability to ´go deep´ was the intention of discussion workshops with the stakeholders. By asking questions that explored a wide range of concerns related to the town square that resulted in a series of themes and possible product ideas to be developed and used further in the following participatory design workshops. The discussion workshops led to a basic understanding of information and to problem finding related to the town square. *¨You feel lonely, vulnerable and monitored in the middle of the square and wish to draw against the facades¨,* said one of the stakeholders. Another stakeholder commented that: *¨The space is undefined and lacks program. It is indistinct what to do there and nothing captures the interest´.* Product ideas ranging from activity spaces, stairs, seating, stepping stones in water and a drinking fountain were some of the ideas that came out of the discussion workshop with the team. Some of these themes and ideas will be explored further in the critical design workshops. Also issues of ownership, alienation, social activity/interaction and the boundaries between private and public space emerged from conducting these discussion workshops.

2.4 Urban Play: Critical (conceptual) design workshops

The second stage of this study is participatory design [10, 14] through critical design workshops, with potential users and a focus group consisting of local citizens. Through an ‘urban play’ workshop with a local high school explorations of what design of *X* might be will be conducted and the development of possible futures/scenarios: What ifs? [7, 13]. The next stage of the research will describe a participatory design framework based on engagement activities via participation [10], by implementing a critical design framework and methodology and testing it out as a participatory workshop, which will take place in Kongsvinger Mars 2015. By using a conceptual participatory design framework for urban planning and the planning of objects for urban space, various forms of knowledge and enhanced support can be integrated for stakeholders´ participation within urban planning. The aim of using such participatory design process is to raise the qualities and values of product design for public space.

By conducting workshops with potential users and further by presenting critical design proposals, the initial aim is to challenge the stakeholders and focus group individually to complete the question 'What if?' with ideas, questions or concerns that come to their minds, related with the proposals and to the topic of public space. Design exploration often seeks to test ideas and to ask ¨What if?¨, but also to provoke, criticize, and experiment to reveal alternatives to the expected and traditional, to transcend accepted paradigms, to bring matters a head, and to be proactive and societal in its expression. Often driven by ideals or theory, design exploration provides what we see as a necessary space for aesthetic concerns in interaction design research [13],

3 FINDINGS

The findings of this study was therefore a result of a series of discussion workshops that involved testing out a critical artefact methodology with stakeholders to see how critical design can contribute to create reflection and debate in and about public space. By challenging the observer to participate in constructing the meaning of the object, their questions, interpretations and criticism becomes part of its meaning. The proposals suggest alternative values to those already enshrined in outdoor spaces and objects, by using a set of means such as estrangement, para-functionality, alienation, social fiction, poetics and cautionary tales. By going beyond function and to explore critical roles for objects by using i.e. estrangement to open the space between people and objects in public space requires discussion and criticism [2, 5] which will be explored in further research. Examples from the case in public space can be transferred to industrial practice, through exploring the concepts of alienation, playfulness and interaction. These experiences can add new dimensions to visual form. The result is a toolbox of concepts and ideas for developing and communicating design proposals that explore issues about public space. The aim was to create a toolbox of strategies for critical design.

3.1 Value fictions

In Design Noir [5], Dunne and Raby argues that one way complicated pleasures can happen through design is through the development of ´value fictions´. Through these scenarios, the aim is to encourage the viewers to ask themselves why the value embodied in the proposal seem ´fictional´ or ´unreal´, and to question the social and cultural mechanisms that define what is real or fictional. This is done by developing alternative and often gently provocative artefacts which set out to engage people through humour, insight, surprise and wonder [5]. The strategy of using such value fictions through the use of conceptual design proposals in discussion workshops with the stakeholders and the local citizens, based on the themes from the focus group interviews are intended findings in the further research.

3.2 Poetic techniques of aesthetic estrangement

By borrowing means from Anthony Dunne, whose attempt to enhance the critical distance between the electronic object and the human subject through introducing and exploring poetic techniques of aesthetic estrangement that is reminiscent of the writing of Walter Benjamin, or the methods of avant-garde theorist/performers such as John Cage, rather than those associated with university-based academic PhD´s in applied electronic engineering [5]. These poetic techniques of estrangement will be explored in the creation of the critical (provocative) artefacts for the critical design workshops and the findings will be demonstrated in the further stage of the research.

3.3 Forms of narratives

Critical design works through narratives that depict fictive social scenarios [5, 14] as a means to visualize alternatives, often even evoking dark humour. Storytelling situates the product in the system of use that allows the user to understand and engage with the design. In some critical design works the story is embedded in the object, through the materials and the form the object takes. The objects function as a critical language through subversion of familiar use and archetypal objects, but with the more speculative critical design objects with more unfamiliar characteristics of objects it requires a detailed narrative. By scenario building and prototyping, the critical artefacts to be used in the critical design workshops, the findings will be achieved through narrative ways of naming, film, photography and can be other mediums than the object itself [5].

4 DISCUSSION

The research aims to map out the possibilities of using critical artefact methods and critical objects to stimulate to discussion about design and design objects. Mainstream and conventional design describes design activity that represents a governing mentality in product design [14]. Matthew Malpass argues that, ′in mainstream design, the market provides strong incentives for designers to participate in economic systems that are arguably beyond individuals' ability to confront.′ [14]. This research argues that by borrowing the means of art and thereby creating discussion about the limitations of product design in public space when it comes to values, relations, user-friendliness and how spaces and objects can limit our experiences. The aim is for this critical design practice to position in a research context is a playful activity that resists and challenges mainstream design and academic stereotype [14]. Through a discussion through a series of critical design workshops, key concepts for a critical design methodology will be outlined. The further work will discuss the potential of design as public/applied art, to improve the values and the quality of our relationship to our artificial environment of public space. In this context the intention is to move from traditional understanding of function into the realms of the poetic, were the critical designer as a researcher aims to encourage reflection on design, design objects and everyday life in public space. Through the critical conceptual workshops key concepts of poetics, para-functionality, social fictions and estrangement will be described as a means to illustrate how critical design can function as an affective medium. The projects therefore also sets out to stimulate to discussion and debate among designers, stakeholders and the public about the quality of public space, developing a position that is both critical and optimistic.

5 CONCLUSION: A TOOLBOX OF CONCEPTS

The research focuses on critical design. The project sets out to develop a design approach and a critical design method for making conceptual design proposals and objects that encourage meaningful reflection on design and public space. The outcome at this phase is the development of some beginning methods and tools to understand and try to create a language of critical design and critical thinking in public space. The results have some common features and thematic categories that will be developed further in the project for the use of design as tools for various critiques in public space.

The intention of the research conducted and in the following project is to design a collection of several conceptual design proposals that shift focus from design and object to the idea and concept, challenging ideas, traditions and the users. The experiments are not for the objects to be a set of practical proposals, but to open up to conversation among the collaborators and viewers about the value that the might embody. The imaginative encounters staged by the objects reflect the mission to provoke a dialogue of the role of objects and the state of design and objects of this time. By challenging the observer to participate in constructing their meaning, with their questions, interpretations and criticism becoming a part of its meaning. The proposals suggest alternative values to those already enshrined in outdoor spaces and objects, by using a set of means such as estrangement, para-functionality, alienation, social fiction, poetics and cautionary tales by going beyond function and by exploring critical roles for objects, through using i.e. estrangement to open the space between people and objects in public space for discussion and criticism [2, 5]. These means will be explored in further research. Through testing out the means of alienation, playfulness and interaction, these experiences can add new dimensions to visual form. Therefore a result is a toolbox of concepts and ideas for developing and communicating design proposals to explore issues about public space when it comes to for instance alienation [2]. The goal is to create a ′toolbox′ of strategies for critical design.

The next phase of this research is a series of workshops that involves testing out the critical artefact methodology [10] in a team with a stakeholder to see how critical design can contribute to create reflection and debate in and about public space. By visualizing alternative possible futures in public space and by redefining the functions and conventions, the next phase will discuss how critical design can be structured and how it can contribute to design for public space by attempts to go beyond conventional definitions of functionalism to include the poetic. The result of the findings of the research and study is to develop a series of tools and models that will enable me to develop my own critical design methodology. The research is to challenge design and hopefully in future work also to challenge the field of critical design. To question how it might adapt to remain meaningful. Such engagement can add value to critical design practice and by extension hopefully add value to the theoretical and methodological foundation [15] of the product design principle and to product design education.

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DESIGNING FOR USER EXPERIENCE IN NORDIC SKIING

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ABSTRACT
Although the experience is the most important aspect of skiing, sports equipment manufacturers do not seem to take this into account in the development of skiing products. This paper examines how the sports industry can develop better products by focusing specifically on the user experience. Such a focus might lead to better experiences in winter sports. A user survey and a literature review were used as the main research methods. The results of the literature review were compared with the opinions and ideas of skiers. The findings revealed a disparity between the users' and producers' focus. Greater involvement of the user and the inclusion of the user experience in the design process could result in better ski equipment and better experiences. A set of design principles is proposed that can be used in the development of ski equipment.

Keywords: Experience, user experience, user involvement, sports equipment, Nordic skiing.

1 INTRODUCTION: BETTER EXPERIENCES THROUGH DESIGN

The focus of the sports industry is on performance, and the Olympic motto of *Citius - Altius - Fortius* [1], faster - higher - stronger, seems to direct the product development of many companies. Thus, the equipment they produce is developed with performance in mind rather than user experience. Although ski equipment appears to be designed only for high-performance skiing, people go skiing for other reasons. For many skiers, the experience is the main reason to go skiing, but equipment manufacturers appear to have overlooked this fact. There seems to be a discord between users' needs and the type of skiing equipment produced by manufacturers. This paper examines *how changes in the development of ski equipment can create better cross-country experiences.* The findings provide the foundation for a discussion on the themes of user involvement and cross-country experiences. Although the focus in on cross-country skiing, the findings may be relevant for the development of equipment for other sports and outdoor activities.

2 METHODS: LITERATURE REVIEW AND USER SURVEY

2.1 Literature: user involvement and experience

The current literature on experiences and user involvement laid the theoretical foundation for this paper. As new themes emerged, the literature selection was revised to get a deeper understanding of the theory. The literature was assessed to develop a solid foundation for the development of the user survey and to gain a deeper understanding of the cross-country experience. The first step in the literature review was an analysis of key topics related to user involvement in the sport industry. The work of Bråtå et al. [2] provided an important source of information on users' roles in innovation processes in the sports equipment industry. An additional goal of the literature review was to shed light on the cross-country experience and to determine how one can design equipment for better experiences.

2.2 User survey: possible ski experiences

A qualitative user survey [3] was conducted to understand what the skiing experience means for cross-country skiers. The aim was to acquire a deeper understanding of users' needs and wishes and not to find a universal truth that applies to all skiers (i.e. the goal was to answer what the ski experience *could be* rather than what the ski experience *is* at present). Surveys offer a broad but basic overview.

Although surveys can be used to determine the views of large numbers of respondents, they cannot provide the level of depth that is possible in interviews [3]. To determine the experiences sought by as many types of skiers as possible, the survey was distributed online both to active and recreational skiers. To gain insight into users' thoughts on skiing, the survey was made up of open questions. As it was sent out in advance of the ski season, the fact that most users had not been skiing for a while may have affected the answers.

2.3 Analysis: concept mapping

A qualitative analysis was conducted to identify similarities and differences between the literature and the results of the user survey. Concept mapping was used to compare and contrast the findings from the literature review and the survey. Concepts from the literature were used to categorise the respondents' experiences in a concept map [4]. The data collection and analysis were carried out in parallel through the research process.

3 USER INVOLVEMENT IN THE SPORTS INDUSTRY

According to researchers at the Nordic Innovation Centre, user involvement in the development of sports equipment is often limited to activities where they have little influence on the design process of the product, such as prototype testing and giving feedback on the finished product [2]. Their report notes that the focus of the industry is to develop better, faster, stronger and lighter equipment and not to create the ultimate ski experience. It also notes that the equipment is often developed in cooperation with both professional athletes and amateur users. Figure 1 shows the users' opportunities to influence the different phases of the design process. The possibilities to influence the design are greater early in the design process, but users might find it difficult to participate at this stage because of the complexity of the product.

Assessing product requirements	Design of concepts	Planning, design	Testing of prototypes	Use of product	Branding of product

←——————————————————————→

(More opportunities; the product is difficult to depict)	(Less opportunities; the product is easier to depict)

Figure 1. Users' opportunities to affect the innovation process [2]

4 EXPERIENCE

The literature on experiences and products often focuses on the experience *of* products [5, 6]. In this study, the experience *with* the products was studied. When skiing, the experience of nature and the experience of skiing are important, not the experience of the skis themselves. The experience consists of several elements, which may overlap. An introduction to some of these elements is presented below.

4.1 Flow

The state of *flow* can occur in several activities[7, 8]. When in flow, a person is so immersed in an activity that nothing else matters. In this state, the person does not think about anything else (i.e. not about the time or place or food), and the activity takes over. Flow occurs when the person has found a balance between skills and challenges and results in a strong sense of achievement. Flow occurs in the phenomenon known as the *runner's high* when an athlete has surpassed himself/herself in physical or technical feats [9]. The concept of flow is particularly applicable to cross-country skiers. In Nordic skiing, flow can occur when the skier goes faster or performs better technically than before and when the skier manages not to fall during a difficult descent. To achieve flow, several conditions must be met. The main conditions are a balance between skills and challenges, concentration and the absence of distractions [7].

4.2 Nature experience

In a study of competitive cross-country skiers, Engeset [10] pointed out that flow was an important part of the experience, especially during hard training and competition. The same study found that the experience of nature was also important for the skiers, with several of the skiers who were interviewed describing the feeling of enjoying nature as the major reason why they skied. Mangen [11] looked in more detail at what the nature experience consisted of in a study of nature as a health-promoting arena, noting that it can be seen as a counterweight to the everyday experience. Mangen [11] highlighted the silence, being alone and the feeling of escape from everyday life as reasons why we seek nature experiences.

4.3 Designing experiences

Most of the literature on creating experiences focuses on interaction and web design, but many of the principles can be transferred to product design. Forlizzi [12] examined the structure of experiences, noting that a rich experience can be built up by several smaller events or activities. Walter [13] discussed the use of *priming* to create rich experiences. Priming refers to small activities that prepare the user for the main experience. Gulden and Moestue [14] discussed how the experience of products can ensure a product's longevity. Chapman [5] and Norman [6] examined the experience *of* products but said little about experiences *with* products. Another study looked at how the tourism industry used design to provide nature experiences and a form of priming to put users into the right state of mind before a nature experience [15]. However, it may be difficult to transfer methods used by the tourism industry to product design.

5 RESULTS OF THE USER SURVEY

The survey provided an understanding of what the ski experience can be for users, and the findings reflected those in the literature. Although the results revealed many recurring themes, the view of the ski experience differed between the respondents.

5.1 The skiing experience

Although the desired experience differed between users, some elements recurred in the survey. Concepts from the literature, such as flow and nature experience, were apparent in different ways in the users' replies. Flow and nature experience are presented as separate concepts in the literature. However, among users, they seemed to overlap. The most active skiers seemed to experience the feeling of flow more frequently than less active skiers. The survey also showed that flow can easily be disrupted, for example, by poor weather proving insurmountable (in terms of skills) and small distractions having an adverse effect on concentration. Several users described their skiing as a sort of escape from everyday life. As noted elsewhere, the feeling of leaving the city can be seen as part of the nature experience [11].

6 DISCUSSION: USER INVOLVEMENT IN DESIGNING SKI EXPERIENCES

As Figure 1 shows, users can be involved in different stages of the design process. In the traditional design process, which focuses on performance, user involvement is often limited to testing existing products and prototypes. In a more experience-based design process, the user is involved at several stages, both to find out what to produce and how the product should work. User involvement earlier in the design process can lead to better skiing experiences, but early user involvement also requires more structure. Figure 2 shows a concept map [4] of two possible design processes in a sports equipment company where the goal at the top of the figure is designing for performance and at the bottom for experience. The upper part of the figure is based on current trends in the sports industry [2]. The lower part of Figure 2 is based on the results of the survey and concept mapping [4]. It shows a hypothetical design process aimed at creating a better user experience. Users are involved in multiple stages of the design process, and only the company alone does the most technically demanding parts of the process. User involvement early in the design process can provide a greater focus on the users' actual needs but requires that they be included and monitored in the design process. The responses to the survey indicate that many users are not aware how their ski equipment can affect their skiing. Therefore, it may be difficult for users to envisage what they really want to achieve in the design process.

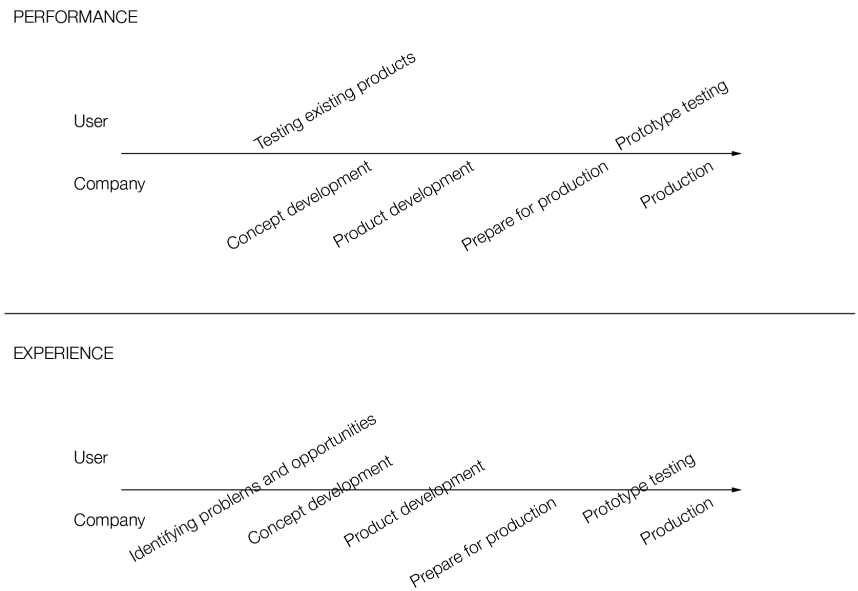

Figure 2. Simplified example of user involvement in two alternative design processes

From the survey, it may seem that the most active skiers are more concerned with finding the feeling of flow and less concerned with the nature experience. The survey was too small for the findings to be statistically significant. However, they suggested that those who primarily use cross-country skiing as a form of training primarily value flow, whereas those who rarely go skiing focus more on the nature experience. However, in a study of cross- country skiers, Engeset [10] reported that the nature experience was important for competitive skiers. Aakre [16] also found that the desire to experience nature explained why some competitive athletes (in this case, professional road cyclists) engaged in sports. Therefore, focusing on the experience of nature may be useful when designing equipment that will be used primarily by competitive skiers.

6.1 Factors affecting the skiing experience

Many factors influence the skiing experience, and not all are under the control of the skier or the designer. In the survey, some of the respondents highlighted factors that cannot be influenced, such as the weather, skiing conditions and environment. Although these factors cannot be controlled, skiers can always adapt to the conditions. A good jacket cannot decrease the wind, but it prevents the wearer from becoming cold while skiing. Similarly, under sub-optimal conditions, the right ski waxes can improve the skiing experience. In sum, we cannot control the weather and snow conditions, but we can ameliorate their effects with appropriate equipment and clothes. Developing better clothes, skis and ski waxes means that we can have good skiing under conditions that previously would have led to poor experiences. Although it may sometimes be difficult to provide good ski experiences, improving the individual elements involved in the experience can help to aid flow among skiers.

6.2 Design principles

This research on user involvement in the design process and skiing experiences identified potential design principles for use during the development of sports equipment. The proposed design principles are outlined below:

- Move the focus from performance to experience,
- Include the user throughout the design process,
- Design for the *whole* skiing experience,
- Use the steps leading to the main experience as priming,
- Remove distractions,

- Make the equipment as simple and functional as possible,
- Allow users to adapt the equipment to their needs.

The proposed set of principles is intended as an addition to existing corporate design principles. The use of the design principles can lead to better user experiences, which, in turn, can lead to extended product longevity and help tie consumers to a specific manufacturer [14].

6.3 Potential solutions and applications

The design principles invert the traditional design process in the sports industry by encouraging manufacturers to develop equipment with a focus on the experience. Gulden and Moestue [14] described how natural conditions can ruin a cross-country experience and how design can ameliorate the effect of these conditions: Some users avoid skiing when conditions require klister (liquid ski wax for wet conditions) because the wax is sticky and difficult to handle. With a new concept for klister packaging, the user avoids contact with the sticky paste and can go out skiing even in difficult waxing conditions [14]. One does not need to redesign the actual ski equipment to make the skiing experience better. Designing for the activities before the ski trip can affect the user experience. The skiing experience can be greatly improved by priming [13]. Priming activities can include ski waxing, transportation to the ski piste and the attachment of skis and poles. From the aforementioned, it is clear that design for better cross-country adventures need not revolve only around creating better cross-country equipment.

7 CONCLUSION: DESIGNING FOR EXPERIENCE AND PERFORMANCE

Manufacturers already involve users in the design process, but they could create better cross-country experiences by involving users in several stages of development. It can be difficult to involve users in the early stages of the process, before product development is underway. However, including users early in the process may result in the creation of products that are better suited to users' needs. Experiences with products are difficult to create because the experience is user specific. Although determining the components of a good experience may be challenging, the design principles described herein can help to facilitate better experiences in winter sports. The industry should concentrate more on the user experience but not at the expense of performance. High-performance equipment can improve all users' skiing. Equipment manufacturers design what users want, but perhaps not what users need.

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USING SOCIAL ENGAGEMENT TO INSPIRE DESIGN LEARNING

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ABSTRACT
Social design and 'design for need' are important frameworks for establishing ethical understanding amongst novice product designers. Typically, product design is a value-adding activity where normally aesthetics, usability and manufacturability are the key agendas. Howard [1] in his essay "Design beyond commodification" discusses the role of designers in contributing to cultural expressions designed to influence consumer aspirations and desires. He argues that designers are impelled "to participate in the creation of lifestyles that demand the acquisition of goods as a measure of progress and status." As emerging consumers, student designers tend to reflect this consumer culture in their work, seeking to add 'marketability' by focusing on aesthetic development. However value adding can occur in many different manifestations, often outside commercial expectations and the students' experience. Projects that may be perceived as having limited market potential can often have significant personal impact for both recipient and designer.
Social engagement provides a valuable insight for design students into the potential of design to contribute solutions to societal well-being, rather than serve market forces. Working in a local context can enhance this, with unlimited access to end users, their environs and the product context, enabling the development of user empathy and a more integrated collaborative process.
The 'Fixperts' social project discussed in this paper has proved to be an effective method of engaging undergraduate students in participatory design within their local community. This model for social engagement has provided an unprecedented learning experience, and established a strong ethical framework amongst Brunel design students.

Keywords: Design for Social Impact, product design education, co-design.

1 INTRODUCTION

It can be difficult to associate design student learning with the potential of design to contribute to communities. Undergraduate students, who may struggle initially with the acquisition of basic design skills, typically lack both confidence in their abilities, and understanding of the practice of design. At Brunel University London, collaboration with the social project 'Fixperts' has provided student insights into the potential of design to address societal problems. This social engagement model requires students to interact within their local communities to discover individual and organisational needs that require design intervention, and to engage with recipients to understand the problem, employing co-design processes, then proposing, testing and building a working solution.

2 DESIGN FOR SOCIAL IMPACT

Papanek noted more than forty years ago that designers had become "a dangerous breed" and proposed that their responsibilities should shift from market driven design towards social and environmental concerns [2]. He advocated new design agendas to address the responsible use of environmental resources and achieve improved societal balance.
However for many years the majority of designers have interpreted their social role as complementary to business strategies and the traditional market-driven approach [3]. Indeed one could argue that, despite the informed narratives of Morelli, Margolin etc and the admirable social design initiatives by leading design agencies such as IDEO, most designers still serve the interests of the more affluent sections of the global community, rather than the needs of those who exist at the base of the pyramid; 'the other 90%'. Victor Margolin referred to "the designer's ability to envision and give form on material and immaterial products that can address human problems on broad scale and contribute to social well-being" [4]. Designers have a responsibility not to ignore the potential of design as 'agents

of change' to make a broader contribution to society, rather than to enhance to market success or influence consumer behaviour.
Product design is a value adding activity that should extend far beyond aesthetics, usability and manufacturability, towards a model where social impacts and design intervention are the key agendas. Designers can play a significant role as "shapers' of society through interventions that encouraging behaviour change, and the corresponding social implications [5].
However, social impact can really only be achieved by understanding the individual and societal needs within their specific social, environmental and economic contexts [6].

3 DEVELOPING A SOCIAL CONSCIENCE

The importance of developing student understanding of design's potential to contribute to less advantaged communities has been well documented (e.g. Morelli [3], Margolin [4,10,11], de Vere [7], Ramiraz [8] etc). Design has a critical role in the well being and betterment of societies, yet design education is often focused on the tools required to service a consumer-product-service model that services the expectations of only the most wealthy 10% of global society. To make a broader contribution, the next generation of design and engineering graduates will need not only awareness of complex cultural, societal and environmental concerns, but also an embedded ethical philosophy that forms the foundation of their learning.
However it is difficult for design educators to impart more than a rudimentary understanding of social design given their locational constraints. Students lack access to the communities and contexts that they seek to assist, particularly as many of the most disadvantaged communities are in remote (often) third world locations. Consequently, the meaningful engagement and participatory design processes that characterise successful social design projects cannot be realised, and design solutions can be 'remote', lacking the local context and user empathy essential for viability and longevity. Consequently, while curricula may contribute to awareness and compassion, students do not feel empowered, or capable of effecting change and making a positive impact through design.
For students to successfully engage in socially responsible design a more local context is required, where students can co-design directly with the target community [9]. A 'design intervention' model within a local (and easily accessible context) can directly aid marginalised groups and individuals (such as the economically disadvantaged, ethnic minorities, and the elderly and disabled) through assistive devices, urban renewal activity, crime prevention and community resource provision. In addition, student learning benefits from enhanced understanding and empathy.
The Fixperts educational project (www.fixperts.org) described in this paper provides an appropriate platform for students to achieve a meaningful social contribution, *within* a local context. User-engagement throughout the design and build process, creates opportunities for students and educators to realise achievable social design projects, and add value to their local communities.
However the most important outcomes for students are the development of a social conscience and the realisation of the power of design to make a positive contribution to well-being and the quality of life. This is an invaluable lesson for novice designers.

4 FIXPERTS

Fixperts was launched at 100% Design in London in 2012 as a platform for designers to engage in their communities and help people with everyday problems. It is an open knowledge and expertise sharing platform whose mission includes the premise that 'fixing' is a valuable creative and social resource and that people should be encouraged to use the power of fixing to solve everyday problems. Whilst 'fixing' can take many forms including repairing and rejuvenating, in this context, design delivers solutions through artefact creation, rather than repair. The premise of the project is not only to create design content, but to document the process with the Fixpartner, testing 'research in the wild' methodologies first hand. Design educational environments are a valuable resource of creativity and enthusiasm, and students are willing recipients of product design experience in a real world context.

4.1 Educational Project

The Fixperts Educational Project [12] has been embraced by several universities worldwide (including Berlin University of the Arts, Kingston University, Brunel University London, and Tongji University in Shanghai). It aims to promote social values through design, and create opportunities for students to:

- make a strong connection between design and problem solving,
- experience working in a collaborative team on real world projects at human scale,

- learn to listen, develop empathy and understand the needs of end users,
- develop strong relationships within their local community and environment, and
- see the impact of direct positive application of their creativity and social engagement.

Brunel Design's engagement with Fixperts has provided a valuable learning experience and a platform to achieve a meaningful social contribution within a local context.

4.2 Fixperts and Fixpartners

The fixperts education model of engagement has four main stakeholders:

- *Fixperts* (people who love to make and improve things – the design students),
- *Fixpartner* (a person within the community who has a 'fixing challenge' and is open to allowing a Fixpert to improve something in their day to day life),
- *Master Fixpert* (a tutor directing student process and solutions), and
- *Film Maker* (to document the process and outcome).

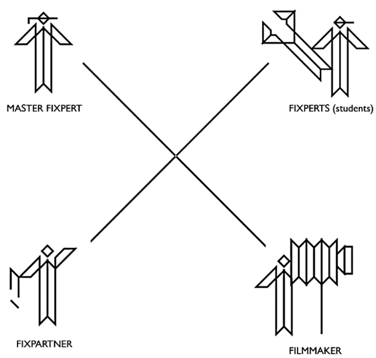

Figure 1. The Fixperts Education Model

In the Brunel Level 1 curriculum, first year BA/BSc students assume both the roles of Fixperts and Film Makers, working in teams of six to identify a suitable Fixpartner, design, test and build a working solution. The students document the engagement and design process in a 3 minute film which is then uploaded onto the Fixperts website (http://fixperts.org/fixfilms/).

4.3 Finding a Fixpartner

The process of securing a suitable project requires students to reach out into their local community and engage with community groups, charitable organisations, neighbourhood businesses, social and sports clubs, and support agencies. The process has to conform to university ethical and safety standards, which are maintained through staff supervision. This requires students to communicate with a broad user demographic, which can be challenging for less confident students, and for those with lower English language competency. We have observed that the relationship that is established between the Fixperts and the Fixpartner is essential to the success of the design intervention, so it is imperative that students quickly establish rapport and avenues of communication. A level of diplomacy is also valuable as students must lead the design process, whilst respecting the opinion of the Fixpartner and including them in design decision making process. However the benefits of this process are invaluable as students develop strong relationships and empathy for their Fixpartner.

4.4 Suitable projects

The project aims to develop on-off solutions to a specific individual or group need. Solutions are experimental prototypes and the Fixperts process is not intended to deliver high-volume manufacturable products, although the potential can exist for project outcomes to be developed further if there is legitimate market demand. Students must approach the process cognisant of the need to work within tight budgetary constraints, and material and fabrication limitations. As Brunel students undertake the project before completing their workshop training, access to machinery and technical

resources is limited, and hand fabrication is often the only viable construction option. This can limit the potential of a project, so initial scoping and project selection critique by tutors (Master Fixperts) plays a vital role in ensuring that outcomes are realistic and achievable. Ideally students are directed to avoid outcomes that may have Health and Safety implications (such as mains electricity, structural loading and stability, dangerous operating environments etc), or ethical concerns.
Students are encouraged to meet with the Fixpartner as a group, and initiate a "Design Scene Investigation", through observation of daily routines and situations that are not problematic or frustrating. Good projects often result from issues the Fixpartner has learnt to ignore or work around.

4.5 Managing expectations

It is important that Fixpartners understand the limitations and scope of project outcomes. Level one students (the Fixperts) are novice designers, still developing materials knowledge and fabrication expertise, with limited resources. Whilst all efforts are made to ensure a safe and well finished "fix" (design solution), the nature of one-off hand fabrication does not result in the levels of finish, quality control and consistent product performance that results from controlled mass-manufacture. This does not mean that solutions are rudimentary and poorly resolved or constructed (as this could lead to public liability issues), but rather that the level of finish will reflect the nature of a prototype rather than a retail-ready product. However despite these constraints, Fixpartners are typically delighted with the engagement process, the contribution made by the students, and the final outcome.

4.6 Documenting the Fixing process

The Fixperts process, culminates with the design prototype being delivered to the Fixpartner, and a three-minute film being produced to document the engagement experience. Students must capture the entire project from initial consultation though all aspects of design development, testing, and prototyping, to footage of the Fixpartner testing the final solution.
Typically students are not experienced in filming and video editing processes, so must quickly develop a filming technique that will deliver consistent light and sound quality during the project to aid the later editing process. Footage must be cut and edited with subtitles, voice-overs, and sound tracks added as necessary. Time-lapse photography and stop motion animation have also proved to be valuable tools to capture extended design and prototyping activity.
These films which are later uploaded to Vimeo and linked to the FixFilms website, must exhibit good quality imagery and an engaging and compelling documentary style.

5 BRUNEL FIXPERTS

5.1 History

Brunel Design has used the Fixperts Education Project since 2013 as a means to support learning in social responsibility, inclusive design and social impact. Approximately 20 student groups (of six students) undertake the project as part of Design Process 1, a 40cp core module in Level 1 for students of the BA Industrial Design and Technology, and the BSc programmes in Product Design and Product Design Engineering. The engagement experience has been valuable in developing understanding and empathy with regard to social issues beyond the students' experience. It has also proved to be a valuable asset to local businesses, charitable organisations and community groups who have benefited from design interventions. The project is run immediately after the Responsible Design project that requires students to develop sustainable solutions to global issues. Whilst the outcomes of that project are largely conceptual, the Fixperts brief allows theories to be applied in a local context with readily accessible environments and recipients.

5.2 Project hurdles

Some barriers to successful project implementation and outcome realisation have surfaced.
As mentioned earlier, students have not completed workshop training when the project commences, and are thus unable to readily access workshop prototyping equipment and assistance. The resultant self-sufficiency with regard to sourcing material and resources is invaluable in reducing dependency on lecturers and technicians. Concerns exist about the safety and durability of prototypes and potential public liability issues, and it is critical that the technical and lecturing staff (Master Fixperts) work closely with student teams to ensure safe and appropriate design solutions.

Students must exercise care with regard to the ethical implications of filming and publishing films in respect to individual rights to privacy and the depiction of children. When working with children and those with disabilities, a great deal of sensitivity and empathy is required during the engagement process, and in documenting the journey. In project where a Fixperts team developed a height-adjustable exercise bench for a girl with disabilities, the child's mother refused to give the students' permission to film the child or her environment. Whilst this placed barriers in regard to the project submission (the documentary film), students countered this by using role play and sketch animation to represent both the problem and the user-interaction with the design solution, whilst respecting the Fixpartner's privacy concerns.

5.3 Process

The Brunel design students use a process that includes exploring, making sense, proposing, testing and iterating (prototyping and filmmaking). There are parallels with Kimbell and Julier's Social Design Methods Menu [12], particularly the process of spending time understanding people's experiences and resources on their own terms, taking methodical steps to analyse and address these with their active participation, story telling, and developing design solutions based on the way people actually do things in their own context. However, the documentary film outcome dictates the students' methodology with user-in-context *filming* replacing *drawn* investigative story worlds, and interaction storyboarding.

Unlike a normal design project, students are not required to submit project portfolios, technical documentation and artifacts for assessment; instead the three-minute documentary film provides the narrative and evidences all stages of the design process.

5.4 Project examples

The types of project chosen by students are diverse reflecting the wider community in which they live. Outcomes can vary from small handle adaptations for the elderly to sporting equipment and specialist transportation systems. The breadth of scope is evident through the project outcomes in Figure 2 and through the FixFilms on-line repository.

Figure 2. Examples of project 'fixes' (from left to right): wetlands bird feeder, kayak carrier harness, adjustable physiotherapy bench for disabled child

5.5 Learning outcomes

The Fixperts education project has resulted in some unexpected learning outcomes. It has been observed that this project (which occurs at the end of the students first university year of design studies), is a 'coming of age' event where the skills they are have learned during the previous two terms are realised in an outcome with tangible and measurable benefits. The satisfaction of developing and delivering a solution to a real world problem, results in a heightened sense of achievement amongst the students, far greater that the receipt of a good assessment grade.

The subsequent boost in confidence across the student cohort has been encouraging, as is the acknowledgement of design as an agent for change. Fixperts has provided a platform for these novice designers to realise their potential and contribute positively to society to improve lives and well-being. There is also evidence of an emerging enthusiasm for design as a profession, rather than a series of university-based creative activities.

5.6 Community benefits

The Fixperts model has obvious benefits to the local community. Individuals, small businesses, sporting clubs and charitable organisations have experienced design interventions that have resulted in social impact through a beneficial design solution, whilst young students have engaged with their local community. Highly individual problems have been resolved in a participatory design/user engagement model that develops empathy and understanding and a community spirit. Engagement with Fixperts has demonstrated to students how they can use their skills to make a positive contribution to their local community, and portrays design as a problem-resolving process that provides beneficial societal solutions, not just consumer products. These are valuable lessons for novice designers.

6 DISCUSSION

Whilst there is value in students exploring their neighbourhood looking for problems, there may also be merit in establishing a repository of people and problems, aligned to a network of local fixers. Student teams could advertise their services in local newspapers and bulletin boards, and local businesses could be encouraged to support the project by funding material purchase. Whilst Brunel Design currently uses Fixperts as a six-week tool for student learning, there is no reason why the model cannot be used as a template for creating active design projects with local community. This could be manifested in the form of a permanent community outreach resource, staffed by students across a range of levels and disciplines.

7 CONCLUSION

The benefits of real world projects on student learning are well established. Industry or community-led pedagogy allows direct engagement with users, and develops empathy and understanding for societal and environmental contexts. The Fixperts Education Project has provided students with valuable insights into the potential of design to resolve societal problems and has helped establish a strong ethical framework amongst Brunel design students. This highly popular project, whilst addressing Papenek and Margolin's calls for a greater social responsibility, provides the means for students to have an immediate societal impact through design intervention. For students, this is highly motivating and rewarding. It is evident that social engagement in a local context is an appropriate process to inspire design learning.

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SOCIAL PARTICIPATORY TEACHING AND LEARNING – LESSONS FROM A PARTNERSHIP OF INDUSTRIAL DESIGNERS AND LOCAL ARTISANS

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ABSTRACT
Regional industrial design education aims to reinvent itself and adapt to local realities, such as the demands of industry and society, while providing object-oriented solutions. Artisan craftsmanship is one particular social demand. The present study therefore aims to better understand the role of industrial design in the production of artisan crafts. The User-Centred Design Workshop (UCD) for third-year industrial design students at the Universidad del Bío-Bío in Concepción, Chile established a collaborative alliance between the "*Fundación Trabajo para un Hermano*" (TPH) Concepción[1] ("Foundation Working in Fraternity, Concepción"), the Universidad del Bío-Bío and artisans affiliated with the group "*Comercio Justo Manos*" ("Fair Trade Hands"). Together participants worked to identify opportunities and potential setbacks related to the micro-production of artisan crafts, from creation to exhibition of jewellery, wooden handicrafts, woven goods, felted products and handmade soap. Solutions proposed by student designers primarily supported artisan production. Participant perceptions were evaluated both during and upon completion of the workshop and covered a range of aspects such as project skills and collaborative work, among others. The collaborative project was well received among students and particularly artisans. Despite differences of opinion, both groups agreed on a number of aspects and positively evaluated the overall methodological focus and results of the project.

Keywords: Design education, participative approach, social integration, regional artisan craftsmanship, collaborative work.

1 INTRODUCTION

Industrial design is a project-based discipline concerned with meeting the demands of both industry and society, working from an objectual dimension to improve quality of life. Adapting and contextualizing the role of design education from the initial stages of the learning process is key for building future designers who are capable of navigating their particular socio-technical environments. Designers are then able to better understand and adapt First-world paradigms to local contexts, such as that of Chile. Known for its developing economy, this South American country has been striving to reduce poverty rates and improve the quality of life of its citizens. Education serves as an important opportunity and exchange value for creating significant social and economic impact.

The relationship between higher education and the labour market, particularly in the field of design, is weak and unclear for the Biobío Region of Chile. Consequently, it is important to develop educational strategies that allow students to effectively enter into and navigate the labour market with attention to the particularities of their immediate environment. On the one hand, industrial design is an activity focused on generating mass-produced goods. On the other hand, the intrinsic value of artisan craftsmanship is not mass production. When faced with craftwork, design is clearly a result and tool of mass industry whose focus is on *production*. On the contrary, craftsmanship is object-based [1].

[1] http://tphconcepcion.com

In terms of its economic significance, with the "shift of the Knowledge Economy towards the Transformation Economy we see new competencies and craftsmanship emerge for both designers and other stakeholders in a design project. As the complexity and intention of design projects change, so do the actions and reflections of the people involved in the process" [2].

At the Universidad del Bío-Bío, the Industrial Design Program has incorporated project development into the design curriculum, thereby promoting capacity building [3] among students where certain skills and information necessary for carrying out tasks [4] help to generate new knowledge for completing assignments [5][6]. Students gain hands-on experience with multi-level design interventions that emphasize the role of social interaction in the profession [7]. The present study explores the collaborative work of students from the 2014 User-Centred Design Workshop (UCD) and 14 local entrepreneurs/artisans affiliated with the group *Comercio Justo Manos* ("Fair Trade Hands") from the Biobío Region. As part of this project, participants identified opportunities and potential setbacks of product manufacturing and presentation. Together with artisans, designers then developed and elaborated proposals for functional products. Studying and analyzing the production of artisan crafts gave students insight into the particular social system and cultures and subcultures of craftwork.

The combination of teaching/learning processes and practical, real-life application of design education was analyzed by reviewing educational strategies that emphasize meaningful learning in industrial design. In addition, an exploratory study was carried out during and upon completion of the workshop, which evaluated the perception of both groups of participants in the following areas: project skills, collaborative work, identity and fair trade, among others. Various aspects of the prototype developed by student designers were also evaluated. Overall, participants gave a positive evaluation of the collaborative experience, especially artisans, who responded extremely well to the project's methodological focus.

2 METHODOLOGICAL CONTEXT

Within the field of design, teaching has traditionally followed project-based design education [8] whereby personal reflection [9] provides students with experiential learning opportunities. Project work has been widely employed as a means for students to incorporate, apply and expand on theoretical knowledge acquired in a classroom setting [10]. User-centred design privileges the role of the user as the centre, beginning and end of the design process [11]. In the context of web applications, users have been called on as key actors in evaluating, providing suggestions on, and even designing aspects of these applications [12]. When applied to product design, a variety of methods are available for recording, systematizing and incorporating user opinions [13]. The User-centred Design Workshop (UCD) focuses on designing products that are based on the needs and desires of real users in real-life contexts [14], starting from the beginning stages of the design process. This involves a shift from "designing for" to "designing with" the user.

3 METHODOLOGY

The UCD project employed a collaborative perspective, uniting the *Fundación Trabajo para un Hermano* (TPH) Concepción [15], the Universidad del Bío-Bío [16] and artisans affiliated with the group *Comercio Justo Manos* from the Biobío Region [17]. A series of meetings between representatives of the participating institutions and groups marked the beginning of this project, providing a space to share concerns and goals for the proposed collaboration. The role of design, the project methodology and concrete needs and concerns of artisans were addressed from an academic standpoint. Additionally, the project focus integrated the following UCD workshop objectives: a) To apply the user-centred design methodology to product design; b) To learn about and apply workshop methods to designing products; c) To actively incorporate users into project development; and d) To promote social integration through design.

3.1 Design Methodology:

The methodological sequence of the project involved the preliminary analysis, development, proposal and approval of a product through a series of phases implemented over time. The phases are illustrated in the figure below:

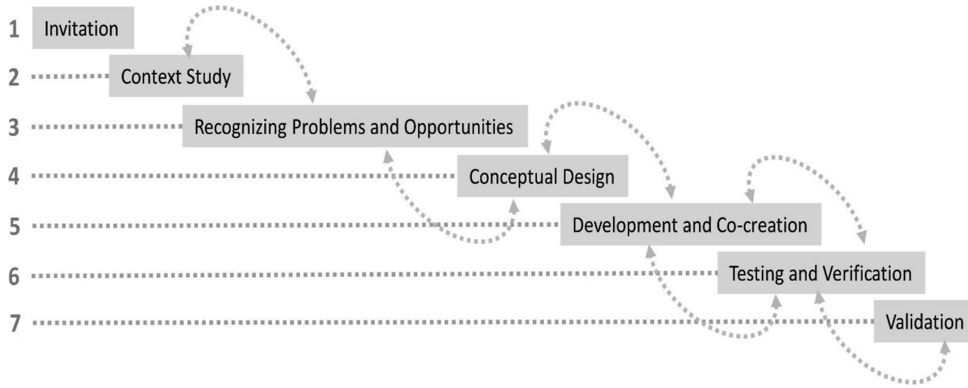

Figure 1. Project Methodological Sequence

3.1.1 Invitation

A meeting was scheduled at the location of TPH offices where artisans were officially invited to participate in the project. During the meeting, project aims were presented and the role of industrial design and objectives of the participatory intervention were explained. This provided a space for sharing the concerns and preconceived notions held by many artisans with respect to institutional collaborations. All participants agreed on project outcomes and final results: a technical folder and functional prototype. A list of interested artisans was also collected.

3.1.2 Context Study

After finalizing the list of participating artisans, design teams were formed with 3 or 4 students for each artisan. An initial plenary meeting was held where participants could socialize in an informal setting. For the first time, student-designers and artisans met, exchanged contact information, briefly discussed the work plan and coordinated schedules. Additionally, students used this time to begin their study of the user (artisan) and his/her work by responding to the following questions: What does s/he do? How does s/he do it? Where does s/he do it?

3.1.3 Recognizing Problems and Opportunities

Fieldwork and participant meetings allowed student-designers to recognize and address problems faced by artisans. This was accomplished using a participatory process where artisans classified and organized design problems through card-sorting. This tool allows users to assign value to problems based on their priority/urgency and the financial and material resources available for developing solutions. In addition, students observed work processes by taking notes and sketches of the unique characteristics and aspects of artisan production, including the tools and spaces used for work.

3.1.4 Conceptual Design

A detailed study of the actions, tools and context underlying problems faced by artisans came together in determining project objectives. The study allowed students to define product attributes and draft a proposal – a theoretical outline of the desired product identity or typology, as well as attributes or characteristics which would solve the problem identified by artisans. A formal examination carried out by students led to the conceptual design of products that represented general qualities and functional and ergonomic principles.

3.1.5 Development and Co-creation

Scale models were created of the selected proposals and were accompanied by scale models of products and elements that interacted with the product. Through storytelling users were able to simulate and demonstrate how they would use the product, thereby allowing student-designers to note overlooked aspects and successful outcomes. Basic materials such as cardboard, clay, etc. were utilized so that the user could modify and adapt proposals, thus engaging users on a creative and decisive level.

3.1.6 Testing and Verification

During this stage, student-designers developed an initial prototype outlining key design details and parts and pieces chosen for their materiality and availability in the region where artisan products are manufactured. Key aspects of usability related to product action and manipulation were tested, and users verified whether functional goals were achieved.

3.1.7 Validation

After the last stage of feedback, student-designers constructed a final functional prototype. The prototype was then presented to the artisan together with a brief survey soliciting feedback. Artisans tested the product for one and half weeks and then completed the survey. This encouraged users to document whether products complied with their stated function and usability, among other aspects.

3.2 Exploratory Study

An exploratory study [18] was carried out using surveys administered to participants during and upon completion of the workshop. Surveys documented both student and artisan perceptions of the following aspects: project skills, collaborative work, identity, fair trade, knowledge and tools. Surveys also included a final evaluation of the product submitted by student-designers. The study provided insight into the various perspectives of artisans and students and identified any major differences between both groups in their evaluation of the project.

4 RESULTS

Fourteen functional prototypes of proposals were constructed, which directly responded to the immediate needs and problems faced by artisans. In addition, the project resulted in the following outcomes: 1 product proposal for an artisan craft; 4 product displays and holders; and 9 proposals for improving product manufacturing, ranging from tools, tool organizers, work materials and workplaces. Project skills, collaborative work and evaluation of the prototype, in addition to pre- and post-workshop expectations of students and artisans, were evaluated using surveys. The results are as follows:

4.1 Skills

Both students and artisans developed a number of skills throughout the workshop, including oral speaking, artistic expression in modelling and/or sketching and prototyping and production using a variety of materials. When considering "team leadership," artisans and students showed a significant difference in ability: 86% of artisans felt that they possessed leadership skills compared to 54% of students. Oral speaking and written communication skills were also more developed among artisans (71% possessed these skills compared to only 30% of students). Finally, product modelling was more developed among students (68%) than artisans (14%).

4.2 Collaborative Work

When asked about the purpose of collaborative work, 95% of students from the UCD Workshop considered collaboration as a way to share ideas, responsibilities and accomplishments. Eighty percent of collaborative work was carried out between artisans and students of the UCD Workshop in face-to-face meetings. The remaining 20% of collaborative work was performed long-distance using different media such as email, group messaging, blogs and Facebook. Regarding the positive aspects of collaborating with students, 80% of artisans commented that the project was successful, noting the opportunities it provided for visualizing problems and solutions as well as sharing ideas. Advantages according to students include: the ability for both students and artisans to work in a collaborative setting, followed by the opportunity to understand different workplaces and contexts where artisan crafts are made, as well as different applications of design in craftwork. Moreover, students valued the freedom in choosing work hours and building a strong commitment to their work. They appreciated receiving feedback from artisans, learned how to develop solutions for emerging problems and confronted new situations with enthusiasm. Nonetheless, one principle disadvantage of collaborative work according to students and artisans was the challenge of coordinating meetings, considering the different responsibilities and obligations of each group outside of the project.

4.3 Evaluation of the Prototype

With regards to the overall evaluation of prototypes developed in the UCD Workshop, in 90% of cases artisans gave a positive assessment. Artisans stated that prototypes provided solutions to some of the problems expressed during the workshop, were easy to use, adapted to conditions of their environment as well as time requirements and work processes and generally improved their work. Each artisan was presented with a prototype; 64% of cases sought to improve production processes while 36% were directed at exhibiting artisanal products. Ninety-two percent of artisans were pleased with the prototype's form; 84% of artisans felt that the prototype was easy-to-use; 92% agreed that it fulfilled aims and objectives of the proposal; 92% described the prototype as 'reliable'; and finally, 85% of artisans considered the prototype to be durable and long-lasting even with constant use.

4.4 Perception and Expectations of the UCD Workshop, Before and After

An analysis of survey results showed that participant expectations at the beginning of the workshop were particularly high among students, who also gave a positive review of the overall project. Opinions following the end of the workshop were more disparate: students negatively evaluated some aspects of the workshop methodology, despite giving the overall UCD workshop a positive review. Artisans positively evaluated the workshop from the beginning through the end with few exceptions. In particular, the inability to coordinate working hours with students was one aspect that hindered the collaborative process.

5 CONCLUSIONS

Incorporating design into other disciplines, such as craftwork, makes it possible to identify new market niches and develop solutions which not only stimulate product growth, but also optimize production processes. Moreover, it enables the design and development of specific tools that identify and improve artisan work processes, thus allowing for further application and development of the discipline.
The institutional collaborative alliance (Top-Bottom) complemented by a participatory focus provided a foundation for engaging with, sharing and integrating the experiences of both students and artisans (Bottom-Up) in developing appropriate solutions which considered the socio-technical resources available for product manufacturing.
Positive reception of the project methodology by artisans may be understood in light of similarities between the "creative processes" of both disciplines (craftwork and industrial design), which follow from ideation to production. As a result, participants shared a common language and purpose that helped support and facilitate collaboration.
It will be essential to consider the right balance between supporting production and retaining the essence of craftsmanship, which emphasizes originality and values the product and/or the production process. The participatory process outlined here is a framework for presenting artisans with design methodologies that, if necessary, may be applied to future product development. Further research should consider the development of a methodology for "designing" artisan crafts.

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Chapter 10

Bachelors, Masters and PhD in Design Engineering

WHAT DESIGN STUDENTS THINK ARE HOT TOPICS; AN ANALYSIS OF 20+ YEARS OF INDUSTRIAL DESIGN MASTER PROJECTS

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ABSTRACT
This paper analyses the topic choice of all 286 final year master projects done at the Department of Product Design at NTNU. Master theses were categorized using five categories: primary focus (interaction design, product design, strategic design and service design), application topic, form of cooperation, primary user focus, and gender of the student. For most of the a priori formulated hypotheses we could find support: Interaction design, service design and design for health care and welfare have become much more popular in recent years, and it is often female students that choose a focus on health and welfare, and children or elderly. Also, projects done in cooperation with public services become increasingly popular. The developments in students' preferences are well in line with NTNU's and the department's research strategy, and reflect the broadness and relevance of design throughout society.

Keywords: Industrial design, final project, Master thesis, curriculum development.

1 INTRODUCTION

The role of industrial design in companies has broadened drastically in the last decades as companies sought new ways of profiting from the skill set of designers [1,2]. One of the roles designers have is to follow societal and technological trends, to understand and prioritize what is important for customers, and to translate these into concrete ideas for products and services for the company in line with its strategy using a range of different ideation and visualization techniques [3]. The role of industrial designers is acknowledged in an increasing number of industries, and they interact with an increasing number of different stakeholders, and are often instrumental in facilitating communication between them about product ideas, product portfolios, and building customer relations. Industrial designers no longer only design products, but also conceptualise services, product service systems, and systems. Based on earlier surveys, the role of the designers has developed from an aesthetics focus to holistic thinking, from one material to many materials, from one product to complex systems, from functionality to identity, from concrete to virtual, and from individual work to team work [4].
These developments have had their impact on the development of industrial design curricula in the past decade. Design students are trained to holistically approach the user, exploring users in the context of everyday life; they are trained to visualize the intangible, and to find integral solutions addressing all stakeholders that interact with the solutions over its life time [5]. Industrial Design education requires that students become trained in both rationality and free creativity [6], problem finding has become equally important as problem solving and solution detailing. Thus, design students need to be trained in designerly ways of thinking in order to address product design problems [7].
Many industrial design curricula are built up in a way where in the bachelor phase the majority of course modules address design challenges where students are handed over a design topic or even specific design brief preselected by faculty members. In the master phase, students gradually get more freedom, or are even completely free to select a design related theme they want to take on. In the industrial design curriculum at the Norwegian University of Science and Technology (NTNU) this is in particular the case for both the 30 ECTS final project during the last semester and the 22,5 ECTS specialization projects in the preceding semester [8]. It is to be expected that project topic choice in this phase of the curriculum would reflect the broadening of industrial design as briefly sketched above. Among teachers, often heard discussions address how interests of students seem to have shifted

over the years, for example from product design to service design, and to interaction design or interface design. To the knowledge of the authors, literature does not provide quantitative or qualitative analysis of topic choices by industrial design students.
This paper aims to collect and analyse empirical data of how student topic preferences have shifted over time. We feel this may serve three goals:

- It will provide empirical evidence for the broadening of industrial design, both as teaching subject and as profession;
- It will provide us with the possibility to test a number of hypotheses based on common expressions of opinion of how students' interests have developed over time;
- It will provide us with information that will be fruitful for the continuous improvement of our Industrial Design curriculum.

2 METHOD

The basis for our empirical material is the 5th year master graduation project course at the Norwegian University of Science and Technology's master program in Industrial Design, which graduates about 25 students a year. Empirical data was collected from all 286 final projects delivered since the industrial design curriculum was established at NTNU in 1993, with the first students graduating in 1997. This was possible as all projects have been archived as both hard and soft copies. Consequently, the data spans 18 years (master projects from 1997 to 2014), allowing for a comparison over time.

2.1 Categorisation

Each final project was categorized using 5 parameters, primary focus, application topic, target user, cooperation partner, and gender of the student. Each parameter is discussed in some detail below.
1. Primary focus
All final projects were divided as belonging to either product design, service design, interaction design or strategic design. Though this may be perceived as an arbitrary division, in practice it reflects very well an almost mutually exclusive way to categorise master projects.

	Result	Methods relatively specific to the focus
Product design	Physical product, often with focus on form, colour, function, manufacturability	Sketching, Computer aided design, digital visualization and rendering, physical prototyping, physical user testing
Service design	Immaterial service, often with focus on user experience	Service blueprinting, customer journey analysis, stakeholder mapping, paper prototyping,
Interaction design	Interface design, often related to screens (touchpoints, mobile devices, webdesign)	Wire framing, information visualization, GUI methods
Strategic design	Design strategies, processes, product portfolio, branding/marketing strategy	In-company interviews, competitor benchmarking

A secondary focus was initially considered and used for a further granulation of the projects' topics. This parameter was meant to help distinguish between focus on sustainability, usability, aesthetics, tactility, materiality, and so on. However, in practice it turned out to be challenging to choose one secondary focus, as many projects addressed multiple topics to some degree, and assessing to which degree would have been a too arbitrary and time-consuming process to complete.
2. Application topic
All projects were categorized according to topic of application they were aimed at. Following an organic process where a large number of application topics were initially distinguished as the categorization process went on, the topics were condensed into Healthcare and Welfare, Communication, Furniture, Logistics, Offshore, Sports equipment, (Other) Professional Equipment, Food and Packaging, Life style and household products, Tourism, Building and Architecture, Professional and leisure clothing, Education, Humanitarian Aid and Public Spaces.
3. Target user
A third category was used to distinguish between the target user for the final proposed product, service, system or strategy. A distinction was made between Average professional users, Average private users, Elderly, and Children. With 'average' it is indicated that no other demographic characteristics than professional or private use was relevant for these categories. This fourth category was included to test the hypothesis that over time, students have focused more on addressing users that

may not be researched using conventional user research methods based on interviews, surveys, or other forms of active participation by the user.

4. Cooperation

A fourth category addresses whether the final project was done in cooperation with industry, a research organization (such as NTNU or SINTEF, a main Norwegian research organisation) or public services, or was done as a personal project without direct cooperation with a third party of interest. Cooperation with design agencies was categorized as industry cooperation, though such agencies may have had public services as clients, which may also be true for projects in cooperation with SINTEF.

5. Gender

Finally, the gender of the student was noted to verify to what extent this may have influence choice of final project topic over time.

2.2 Categorisation process

The categorization of every master project was done by a single staff member, who has had the role of study program leader (whose role, among other things, includes responsibility for coordination of the final projects) for many years, and has been employed at the department since 2001. This staff member remembered most final projects which facilitated categorization. Another advantage of a single staff member doing the categorization was to avoid differences in interpretation of the categories. The data was stored in MS Excel and analysed using a variety of its mathematical functions.

2.3 Hypotheses

Before the analysis was done, and to make the exercise even more interesting, all scientific staff members connected to the department were approached to informally share their biased opinions about how they think final project topics may have developed over time. Some of the hypotheses that were created by combining these opinions are:

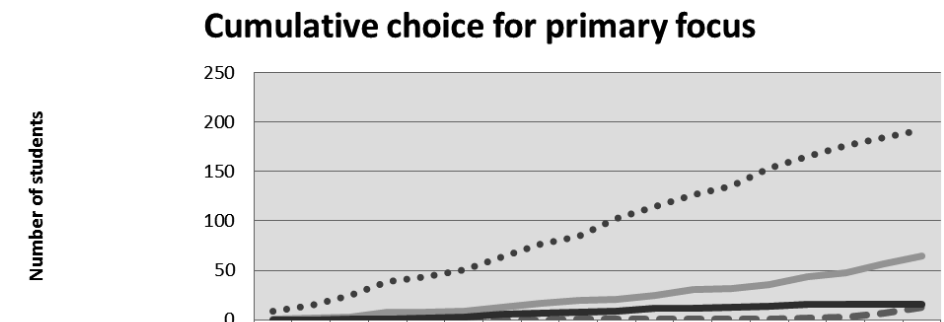
1. "Interaction design has gradually become more popular in the past 10 years or so";
2. "Service design has suddenly become more popular in the past 5 years or so";
3. "Design for health and welfare has suddenly become more popular in the past 3-4 years or so";
4. "It's often female students that choose for design for health and welfare and service design";
5. "It has become more common to cooperate with actors from the public domain";
6. "Female students choose interaction design, male students choose product design".
7. "Perhaps are furniture projects done by students as personal projects when they cannot find a company or public service to cooperate with?"

3 RESULTS AND ANALYSIS

This page limit for this paper does not allow for presenting the complete set of results. Therefore a selection is made, focusing on the most interesting results from a departmental perspective, with particular attention for verification of the hypotheses.

3.1 Parameter 1: Primary focus

Table 1.Cumulative results for choice of primary focus



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Product design	9	15	25	39	44	51	64	77	85	102	114	126	135	153	165	176	184	192
Interaction design	1	2	3	8	8	9	13	17	20	21	25	31	32	36	44	48	57	65
Service design	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	3	7	13
Strategic design	0	0	1	1	2	3	6	7	8	9	12	12	13	14	16	16	16	16

Table 1 presents cumulative numbers for the choice for the final projects' primary focus. The most interesting observations here are that product design has, until 2012, always been more popular than the other areas, but that interaction design has been equally or more popular in the last few years, confirming the first hypothesis, though the increase in popularity is more recent than assumed. Service design has only really emerged as topic since 2013, which is also more recent than thought with hypothesis 2 in mind. Interestingly, no students have chosen strategic design since 2012.

3.2 Parameter 2: Application topic

Table 2 lists for 1997-2014 the number of projects that focused on the various industry branches, with a further breakdown per primary focus. The application topics show a good spread across a large number of industries, where in particular the healthcare and welfare services, and the communication industry are well represented. Of all healthcare oriented projects, about 50% has been done in the last four years, confirming the impression that led to hypothesis, although health care and welfare design has from the start been present among the students' topic choice. Topics related to health and welfare design have often a more than average component of mapping user needs, and often address the challenge of mapping needs and wishes for users that may be not be reached through conventional user centred design methods, because of age or illness. Projects range from developing specific products such development of medical equipment, to interfaces for home medication or navigation, to hospital or medical group practice services. In recent years, health care and welfare design is an explicit element of the department's research strategy, as design research is seen as having an important contribution to developing more efficient and user friendly solutions in this field [9,10]. Within the healthcare and welfare domain, the vast majority of the products are done with in cooperation with a partner from the public services.

For all topics except tourism and education, product design dominates over interaction, strategic and service design. Unsurprisingly, the percentage of projects within the communication industry has a relatively high share of interaction design oriented projects, whereas furniture projects, with one exception, are all product design oriented projects. The fact that communication, furniture, offshore and sports equipment all score relatively high in popularity can be partly explained by the fact that these industries are relatively well represented in Norway and as such offer student interesting opportunities for cooperation. In light of hypothesis 7 it found that students choosing for furniture related project almost exclusively work with industry projects, with only a few exceptions choosing this as personal project.

Table 2. Application topics: totals and breakdown per primary focus

Application topic/ Industry branch	# projects 1997-2014	% of total	product design	interaction design	strategic design	service design
Healthcare and Welfare	44	15,4 %	29	11	0	4
Communication	40	14,0 %	22	14	1	3
Furniture	32	11,2 %	31	0	1	0
Logistics	31	10,8 %	23	6	2	0
Offshore	27	9,4 %	13	12	2	0
Sports equipment	22	7,7 %	18	3	1	0
(Other) Professional Equipment	15	5,2 %	8	1	5	1
Food/Packaging	14	4,9 %	10	1	2	1
Life style/household products	14	4,9 %	10	1	2	1
Tourism	12	4,2 %	3	7	0	2
Building and Architecture	11	3,8 %	7	3	0	1
Professional/leisure clothing	11	3,8 %	11	0	0	0
Education	7	2,4 %	2	5	0	0
Humanitarian Aid	3	1,0 %	3	0	0	0
Public Spaces	3	1,0 %	2	1	0	0
Total	**286**	**100 %**	**192**	**65**	**16**	**13**

3.3 Parameter 3: Target user

Over the full 18 year period, about 51% of all projects were done with mainstream individuals in mind as end-users, 34% for professionals, 10% for children, and 5% for elderly and handicapped persons. No clear trend can be determined regarding the division between professionals and children, though projects aimed at children and elderly have become more popular in recent years; in 2012 44% of all projects, and in 2014 32% of all products were done with these user groups in mind.

3.4 Parameter 4: Cooperation

It turns out that about 80% of all projects over the years were carried out in cooperation with an industry partner, 10% with public services, 5% with a research organization (NTNU or SINTEF), and 5% as an independent project. Projects with public services have become increasingly popular since 2012, as 20 out of 29 projects in cooperation with public services were done in the last three years; in 2014 these even made up almost half of all projects. This supports hypothesis 5.

3.5 Parameter 5: Gender

Strikingly, we found out that the 286 delivered master projects were divided exactly equally between female and male students. This image of emancipation is visible throughout the existence of the study program, with maximum majorities of 72% (for male students in 2008, for female students in 2014).

It was analysed how gender affects choice of focus and topic. There is no pattern that suggests that female students prefer interaction design over product design, falsifying hypothesis 6. But what is striking is that all 13 students that have chosen service design over the years were female. Another interesting result is that since 2010, when the end user focus on children and elderly started to gain interest, 77% of all projects focused in these areas have been done by female students, often in cooperation with a partner from the public services such as hospitals or other health services; in cases where an industry partner participates, is this usually a design agency, with a public service as client. This clearly suggests support for hypothesis 4.

4 DISCUSSION AND CONCLUSIONS

The analysis of the results has provided insight about to what extent the teachers' 'gut feelings' about how students' preferences about topics to take on in their master projects have developed over time. In most cases, these gut feelings have been confirmed. The preferences have indeed changed over time, and interaction, health care and welfare design, service design, cooperation with public services, as well as a focus on children and elderly can indeed be observed, though changes are mostly from a more recent date than expected. The changes in focus are well in line with the department's research strategy which is made up of interaction design, health and welfare technology (which is also one of NTNU's research focus areas), and social and innovation design.

In the development of the department's new study program which was initiated in 2012 and is currently in its 3rd year of offering the new study program which, in addition to a new number of new courses, offers the two study specialisations product design and interaction design. In the fourth year, from summer 2015, a new course will be offered called Design for Society, which will, more than before, create space for addressing societal challenges (in particular health care) and introducing service design methods as part of the designer's tool box. The increased attention for service design topics may to some extent influence the requirements for deliverables in final master projects, where the final result is usually not a concrete product or interface, as it has been traditionally. Implementing and testing services is often experienced as more time consuming, and final results are sometimes regarded by external assessors as a proposal for a concept rather than a proven one.

On a last note, developments in students' preferences reflect the broadness and relevance of design throughout society; this was already visible close to twenty years ago, but holds even more truth today. Although not researched in detail, we see that students, more than before, find jobs in all industries, be it as designer, product manager or consultant. Designers with educational experience in interaction design and service design seem today especially in demand, based on feedback and inquiries directed to the department, and based on feedback from students that embark on the job market.

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INTRODUCING INDUSTRIAL DESIGN TO THE STUDENTS OF RENAISSANCE ENGINEERING PROGRAMME: A PERSONAL EXPERIENCE

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ABSTRACT
Nanyang Technological University (NTU), Singapore, founded in 1991, is amongst the largest engineering universities in the world. NTU offers an integrated engineering programme that admits about 50 elite students, awarding a dual-degree comprising of Bachelor of Engineering Science degree and Master of Science in Technology Management. Called the Renaissance Engineering Programme (REP), this is a rigorous 4.5-year programme with a curriculum that intends to bridge engineering, business and the liberal arts which includes design. The intention is that the REP graduates would master and possess the necessary knowledge, skills and attributes within the broader context of engineering science to become future leaders.
During the second year, REP students take a compulsory module titled *RE8007 Aesthetics and Design in Industry*, which gives the students an idea of the importance of aesthetics and the relationship between form and function and how user experience can influence industrial design decisions. As the instructor of this module, the author experienced first hand, how REP students cope with abstract concepts, the creative process and execution methods of industrial design. This paper candidly discusses the issues of teaching industrial design to engineering students with an expectation that, together with what they gain from other engineering design modules, the students will possess the wherewithal to become designers capable of solving complex problems upon graduation. This paper discusses ways to improve the approach to teaching integrated design and how this has panned out in the effort to introduce industrial design to REP students.

Keywords: Industrial design, engineering design, curriculum, integral design

1 INTRODUCTION

Nanyang Technological University introduced the Renaissance Engineering Programme (REP) in the year 2011 with the aim to provide an integrated approach to teaching engineering to a carefully selected group of students who are high achievers (top 2%) in their high school leaving examinations (A-Levels or IB Diploma or Polytechnic Diploma or equivalent) and show potential, during selection interviews, to study in a multi-disciplinary programme that is meant to connect engineering, business and arts and social sciences. At the end of four and a half years of study, REP, students are expected to have mastered and 'possess the necessary knowledge, skills and attributes within the broader context of engineering science' (http://www.ntu.edu.sg/REP/Pages/default.aspx). Students admitted to REP study a common programme for the first two years and chose an area of specialisation in Year 3 and 4 in one of the following areas of discipline: Biomedical Engineering, Chemical Engineering, Civil & Environmental Engineering, Computer Engineering, Electrical & Electronic Engineering, Materials Engineering, Mechanical Engineering, and Aerospace Engineering. The highlight of REP is also the one-year of study during the Year 3 at the University of California, Berkley or Imperial College, London followed by an internship in USA or UK.
If the selection of the students is very stringent, selection of 'REP Fellows', the faculty who teach in the REP programme, is very strict, with multiple interviews with the Director of REP programme and other REP Fellows before being admitted to teach in REP. REP Fellows are selected from different colleges and schools within NTU. The author was selected from the School of Art, Design and Media to teach a second year course titled RE8007 Aesthetics and Design in Industry. Taught as a 'seminar'

course, RE8007 aims to 'introduce the REP students with a broad understanding of industrial design and acquaints them sufficiently to work with the creative professionals who influence not only the aesthetics of products and built environments but also the user experience and, to an extent, the manufacturing of such products and built environments'. While the author, a trained industrial designer with a mechanical engineering background, enjoyed teaching the first cohort of 35 students and the second of 56 students, the Student Feedback on Teaching (SFT) from both the cohorts revealed another side of the story. The students revealed some interesting facets to teaching an introductory course on industrial design to an elite group of engineering students, which set the author on a pursuit to understand what needs to be done if such a course is to be taught to engineering students.

This paper looks at four aspects in discussing the experience of introducing industrial design to REP students:

1. What is design as understood by design schools versus engineering schools?
2. What is the expectation on design course(s) taught in REP from NTU versus REP students?
3. Results of student work from 2012 and 2013
4. How could design be taught for a specialised course such as the REP?

The author also takes a small detour to highlight other programmes that are similar to REP in order to compare how design is taught in such programmes.

2 DESIGN IN DESIGN SCHOOLS VS DESIGN IN ENGINEERING SCHOOLS

Design means different things to different people. Sathikh [1], in a paper titled *Mapping design curriculum in schools of design and schools of engineering* highlights the main difference between the understanding of design by design schools and engineering design. Design schools tend to take a generic definition of design at the first level since many of them allow students to specialise in very focused areas of design such industrial design, visual communication, interaction design, etc. Engineering schools, on the other hand, equate design to engineering design with reference to product design and/or industrial design within 'design' modules. This means that there is a clear difference in the accent of design in these two schools, which is reflected in the way the curriculum is developed by the two schools. Sathikh [1] has compared the typical curriculum for undergraduate programmes in industrial design and engineering that can be summarised as:

- Industrial design lays more emphasis on use and function with reference to the final user, in what may be termed user centred approach to design.
- There is greater emphasis to subjects that sensitises students to aesthetics and emotional aspects of products/objects within the built environment.
- Engineering design curriculum lays more emphasis on use from the viewpoint of function drivers or component and system elements.
- Engineering design curriculum is interested in teaching the students about optimising such function drivers for efficiency, manufacture and cost with little attention to emotional aspects of design.

This is corroborated by the definition for industrial design from NASAD, National Association of Schools of Art and Design (http://nasad.arts-accredit.org/) and the definition for engineering design from ABET, Inc., the recognised accreditor for college and university programmes in applied science, computing, engineering and technology in the USA. NASAD states that 'industrial design involves the combination of the visual arts disciplines and technology, utilizing problem-solving and communication skills' while ABET defines engineering design as 'the process of devising a system, component, or process to meet desired needs'. All this points out to two distinct professional aspirations that need to work together for successful design of products allowing space for each other, which means that one has to learn some aspects of the other to build a harmonious process of product development.

3 EXPECTATIONS OF DESIGN COURSES IN REP

It is important to look at the first two years of study at REP since this represents the multi-disciplinary study period before the students embark on the area of specialisation and head off for their study year to USA or UK. There are practically no course modules on design during Year 1 of REP. In Semester 1 of Year 2 there are two key courses on design, namely Build and Test Project and Aesthetic and Design in Industry. In Semester 2 of Year 2 there are two more course modules that are design related, namely Integrated Design Project and Design and Systems Engineering. The expectation from REP management was that, by the end of Year 2, students must have the wherewithal to design and develop a whole range of products and services with due considerations to aspects of industrial design and engineering design including material, costs, manufacture, marketing, etc. That is a tall order, if one is to consider that there were no introductory or foundation modules, neither in industrial design nor in engineering design. This is in addition to the large workload from traditional mathematical and engineering subjects that are compulsory for Year 2 students.

Being high achievers, REP students take up the challenge to read up on what is being taught. In understanding abstract concepts associated with aesthetics and design, however, REP students seem to have difficulties. This handicap is further magnified when they need to continue with Design and Systems Engineering and Integrated Design Project in the following semesters, during which time, REP students are expected to learn CAD skills on their own, which adds to the difficulty of taking design forward. It is in this context the author experienced, first hand, the challenge of teaching Aesthetics and Design in Industry for the first two batches of REP students.

4 EXPERIENCE OF TEACHING AESTHETICS AND DESIGN IN THE INDUSTRY FOR THE FIRST TWO BATCHES OF REP STUDENTS

The first batch of REP class had 35 students while the second batch was significantly larger, consisting of 56 students. Placed between a studio/seminar class and a lecture format, the Aesthetics and Design in the Industry class, with three contact hour per week for a total of thirteen weeks, had to be meticulously planned with lectures, video screening, class assignments, visits and projects for every week. Students were clearly told that this course introduces them to industrial design and is meant to familiarise them with the field so that they will be ready to work with designers in their working life. The course started with a trip to IKEA megastore located at Tampines in Singapore. This trip was to expose the students to Scandinavian furniture and aesthetics and to point them to the need for building simplicity through design. A series of lectures supported by class exercises, which utilize information and visuals from the Internet were employed to keep the students occupied. Just after the mid-semester break students were taken to Red Dot Museum in Singapore, followed by a visit to ‘Courts’ an electric/electronics supermarket. The last six weeks were lectures that gave an idea of the relationship of design with different facets of product development. These lectures were supported by presentation of real life experience from the author as well as selected guest lecturers. The author also brought with him actual samples of finished products as well as material samples to show the students. Students were asked to write a term paper on a subject related to design and were asked to design a poster on this term paper. These posters were displayed and each student was asked to vote for their choice based on criteria of graphic design layout. The whole process of voting became an interesting event by itself.

4.1 How was the course received by REP students

The author felt comfortable with the mode of teaching and the response he was getting from the class. Field visits were well received with enthusiastic students following every aspect that the instructions had asked them to observe. Assignments were submitted on time and they were well written. All the indicators were pointing to a successful class. But, when the Student Feedback on Teaching (SFT) was handed to the author for the first time, it was a complete shock!

In both the years, there were only about 30% of students who enjoyed the course, while another 30% were neutral about it. The last 40% of students however, were very critical of the course and the way the course was conducted. Comments ranged from ‘this module was boring’ to ‘the course was not structured properly’ to ‘the instructor did not show us how to design’. There was even a comment that ‘the instructor got away with showing YouTube video clips’. The clips shown were taken from YouTube and other sources, and were usually conversations with designers such as Jonathan Ive of Apple Computers or were from IDEO or were from injection moulding manufacturers themselves, etc., and all were highly relevant. The SFT results for the other three design related courses did not fare any better, with comments such as ‘these courses are not relevant’ or ‘was not presented properly’. To the REP Fellows, who were used to being graded high for their teaching in their respective departments, this came as a surprise. What were the reasons for such a review then? What can be done?

5 DISCUSSION

In order to understand what could be done better to improve student acceptance of an introduction to industrial design in REP, the author looked for similar specialised or elite undergraduate courses in engineering. A paper written in 1995 titled *THE LEARNING FACTORY - A new approach to integrating design and manufacturing into engineering curricula* [2] caught the attention of the author. Started as a project under the Manufacturing Engineering Education Partnership (MEEP) brings consisting of engineering programmes in Penn State, University of Puerto Rico- Mayagüez, University of Washington and Sandia National Laboratories, the Learning Factory aimed to provide 'A practice based engineering curriculum which balances analytical and theoretical knowledge with manufacturing, design, business realities, and professional skills'. The original curriculum build up of the Learning Factory, as envisaged by MEEP is shown in Figure 1., where the foundation to this curriculum is ' Product Dissection, Graphics and Design'. Reading the paper in detail, reveals that during the foundation phase the students 'examine the way in which products and machines work: their physical operation, the manner in which they are constructed, and the design and societal considerations that determine the difference between success and failure in the marketplace. In other words, students need to spend some time to 'dissect' the design elements of existing products in order

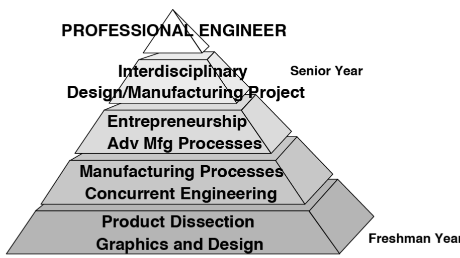

Figure 1. Curriculum build up from the Learning Factory

to understand the relevance of industrial design and engineering design to the overall validity of the products. The Learning Factory today seems to be a part of Penn State as a centre where students can do 'industry-sponsored and client-based capstone design projects' (https://www.lf.psu.edu).

Dissecting products for design and engineering elements does not necessarily give the educational basis for understanding industrial design. Green et al [3] in an article titled *Studio-based teaching: history and advantages in the teaching of design* point to an important element in the teaching of industrial design, namely, the studio, which they (eschewing the ideals of Walter Gropius) point out 'should be a place where studio projects were executed and these should reflect professional practice. The adjunct courses, such as mechanics, manufacturing and materials science, should not be isolated from the project activity in the studio, but rather be complementary to it'. This could be difficult given the context of contemporary engineering education. In REP's case, the idea of a studio-based education seems reflect in the classroom environment where students are clustered into 'desk islands' and are provided with multiple projections, on-line interactivity and other hi-tech accessories. A curriculum structure such as the Learning Factory and conducive classroom environment as in REP alone may not ensure that students will grasp abstract concepts associated with design.

Sathikh [1], in discussing integrating industrial design and engineering design proposes a hybrid model, shown in Figure 2, where the essentials for both fall within the intersection of the Venn diagram. In the author's opinion the course modules that fall within the common area may form a structure for building the essential skillsets and knowledge in design that will be required by students of REP. The other possibility is a combination of what is stated in Figure 1 and Figure 3 which then will allow for the teaching of an integral design curriculum where student get to understand industrial design and engineering design before working on complex projects requiring design. This process can be further enhanced if complex projects are undertaken by REP students together with the (industrial) design students from the School of Art, Design and Media at NTU. In this way both REP and design students can contribute to a successful implementation of integral design projects within each other's curriculum.

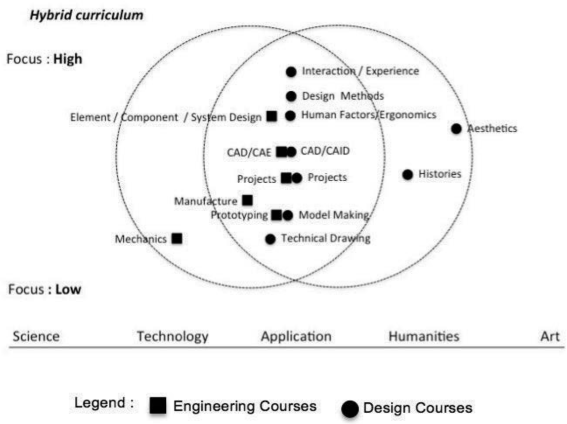

Figure 2. Hybrid curriculum model

Author's' experience of teaching design in schools of design and schools of engineering in the past shows that selecting the topic or course modules, as in Figure 3 and putting them in the structure of the Learning Factory (Figure 1) without a teaching structure and trained/experienced instructors produce a fall back effect to the 'lecture-tutorial' model where the students receive 'canned' goods through lectures which are then verified through tutorials. What could be a possible pedagogy model for REP then?

While the studio-based learning proposed by Green et al [3] seems to fit teaching methods in industrial design and has been the practice of many art and design schools around the world, teaching the concept of industrial design or a hybrid course of Figure 3, there needs to be a level of rigour in terms of introducing the theoretical elements of design followed by design problems that the students could possibly complete. This differs from the open-ended, project based approach taken by most of the design schools. Preparation requirements can also be introduced where students are asked to read and do online research about the project that is going to be introduced. Atman et al [4] in an article titled *Teaching Engineering Design: Can Reading a Textbook Make a Difference?* have studied this possibility as early as 1996 and have found that 'subjects that read the design text before they solved the three open-ended problems spent significantly more total time working on the problems, generated more alternative solutions, iterated significantly, more often through steps in the design process, and considered significantly more design criteria as they developed their solutions to the problems than did subjects that did not read the text before solving the problems'.

To summarise a possible approach to restructuring the teaching of design to REP :

1. Revise the curriculum and syllabus based on the built-up suggested by the Learning Factory [2].
2. Identify key components to teach based on the hybrid model presented by Sathikh [1].
3. Keep the studio environment already in place.
4. String the theory and practice together through a problem based approach.
5. Instead of a complete open ended approach, present the theoretical aspects and general constraints of the problem at hand.
6. Give students tasks to do in terms of reading and researching before hand.

Being high achievers, REP students may prefer the revised design modules better than the way they were presented in the first two years. Was it possible to execute this?

6 CONCLUSION

In trying to understand what did not go well in offering an introductory course on industrial design to the students of the Renaissance Engineering Programme, the author, together with the other instructors

teaching design modules, were able to identify that there needs to be a revision of the curriculum to offer a series of modules culminating in integral design within REP. The first step to interest REP into this integral design could be the ‘product dissection, graphics and design’ approach proposed by the Learning Factory. In author’s opinion before such revised approach could take place, faculty from engineering and design needed take the necessary steps to understand each other’s contribution in the integral design curriculum so that the students will enjoy studying design as part of REP.
The first step towards such integration has already been taken at NTU by the Director of REP who had merged the four design based courses into a series of two modules where REP Fellows who were teaching each of their parts separately were asked to string together the design modules and teach as a team. The first of such integrated approach has already been tested with the team teaching approach in Semester 1 of academic year 2014-15 and the Student Feedback on Teaching (SFT) for this new module from the third batch of REP has been more than encouraging pointing to a right direction in teaching design to REP students.

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READING ASSISTANT: HANDS-ON EXPERIENCE WITH SYSTEMATIC DESIGN

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ABSTRACT
'Product Design, Development and Marketing' is one of the key courses in the Engineering Management Program at UAE University. The course was aimed at enabling the students to fully comprehend the various stages of the design process and the interim outputs that are produced and needed to be produced in a systematic design process. Systematic design process with design models and methods was taught in lecture classes. A carefully chosen design and build project was undertaken to cement the learning. Reading Assistant, a tool assisting readers to have access to multiple open books with ease, was designed and built as part of the course. It followed a systematic design process consisting of five stages namely Requirements, Product Concept, Solution Concept, Embodiment and Detail Design. In the process customer requirements were recorded, specifications were drawn, alternative concepts were proposed and a preferred one was chosen, embodiment was developed and the detail design was completed. The design was analyzed and proven before its committal to manufacture. Manufacturing was considered at every stage of the design process. Several interim outputs were produced during the passage from idea to completion. The project described here is the work of one of the seven student groups from a class of 24 students. This reinforced the structured path that has been followed in the design and development of the product. The course has given a first hand experience in the systematic development of a product and taught a large number of theoretical and application lessons.

Keywords: Systematic design, design teaching, product development.

1 INTRODUCTION

Master of Engineering Management Program at UAE University has Product Design, Development and Marketing as one of its main courses aimed at enabling the students to fully comprehend product and concurrent process development from concept to completion. 'Product Design and Development'[1] was used as the prescribed text. Design models and methods were taught in a series of lectures with appropriate examples. A project has been carried out to gain a comprehensive firsthand experience in the design and development of a product from concept to completion. Reading Assistant is a tool that enables a reader to have a direct access up-to six standard books in open position. The entire class of 24 students participated in the Design and Development project grouped in seven groups. *HEX III*, the product developed by the authors' group is intended to be useful to Researchers, Students, Physicians, Lawyers, Libraries, etc. in such a practical and innovative way that provides easy and fast access to multiple books saving the reader time while keeping the table top neat and clean. The product was developed using a systematic design process that has five stages namely Requirements, Product Concept, Solution Concept, Embodiment and Detail Design[2]. It enabled the students to have definite starting and finishing points together with interim milestones for the entire project from the inception. Also it made the planning of the work more efficient. The course taught a number of design methods[4] that could be used at various stages of the design process and the project gave the opportunity to use some of the chosen ones. It has given confidence to students to start a design project and steer it towards a successful completion. This paper starting with a brief literature survey describes the course, product, learning outcomes and the learning experience of the students.

2 LITERATURE SURVEY

A Design Model describes the sequence of activities or stages that transforms an abstract set of requirement into the definition of a physically realizable product. Cross[3] states that descriptive models outline the activities that typically occur in designing while the prescriptive models attempt to prescribe a better or more appropriate pattern of activities. Systematic Design breaks down the design process into a sequence of stages and handle each stage in detail so that no one stage is overlooked and the entire process is transparent and repeatable. Systematic Procedure had been proponent as an urgent need to improve on traditional ways of working in design because of increasing complexity of modern design. Cross[3] defines the design methods[4] as “any procedures, techniques, aids or ‘tools’ for designing and they represent a number of distinct kinds of activities that the designer might use and combine into an overall design process”. Jones[4] in the sixties started the focus on design methods with his book outlining thirty-five design methods including Brainstorming; which aims to stimulate a group of people to produce many ideas quickly, Synectics; which aims to direct the spontaneous activity of the brain and nervous system towards the exploration and transformation of design problems, Removing Mental Blocks; which aims to find new directions of search when the apparent search space has yielded no wholly acceptable solution, Morphological Chart; which aims to widen the area of search for solutions to a design problem. Developing and refining new design methods is an ongoing research activity to help overcome the difficulties of modern design problems.

3 THE COURSE

The course started with a comprehensive overview of the objectives or what the students have to achieve at the end of the course. An existing simple product, a portable concrete mixer, was introduced and the societal need of it was described. The need was then translated into specifications in a brief fashion. Main purpose functions were then shown. Concepts of the product available in the market were identified and the parts tree for a chosen model was shown. Make/buy decisions that had to be taken were pointed out. This quick walk through of the development process gave the students a reasonably good idea of the process. Design models were introduced after this citing many different examples. Design methods[4], the tools and techniques usable at various stages of the design process followed the design models. Brainstorming, Ideation, Morphological Analysis, Decision-Matrix, Pugh’s[6] concept selection, and parts-tree analysis are some examples of Design Methods taught in the Course. Approaches to conceptual design were described and the detail design was divided into two parts. The professor explained that in the first part called Detail Design every component needed are identified and put in place. In the second part called the Detailed Design all the necessary engineering considerations are identified and detailed analyses are carried out in these areas to prove the soundness of the design. The outputs at various stages were explained and the professor emphasized the importance of defining the needed outputs right at the beginning. In the development of the Reading Assistant project the following outputs were considered:

Table 1. Shows the anticipated learnt output for each design stage of the overall design process

Stage	**Anticipated Output**
Initiation of Project	Brainstorming, Targets sets, Time Schedule
Extraction of Mission Statement “Design Brief”	Carefully listening, Constructive Thinking
Establishing Needs	Evaluation of needs, its importance and Needs Metrics Matrix
Product Concept	Functions Analysis, Function Diagram
Solution Concept	Morphological Analysis, SCREENING / SCORING Matrices
Embodiment	Parts Tree, Make/Buy decision
Detail Design	Bill of Quantity, Drawings of all parts included
Detailed Design	Engineering Stability[7] Calculations
Manufacturing	Technical on-hands skills
Marketing	Roles Distribution, Marketing 4Ps
Project Close-Up	Results and Conclusion, Lessons Learnt

4 THE PROJECT

4.1 Methodology

The prime task at the beginning was to understand the project in full and making a comprehensive plan with interim outputs and milestones. A lot of handholding and collective work with the whole class were needed at the beginning but once started the students groups went independently in their own ways. The project started by interacting with customers, which included Professors, Research Students, Lawyers, etc. and carefully listening to their voice. Their verbatim was recorded and later translated into needs. Metrics that could deploy the needs were identified after this. Chosen needs were then referred back to the customer to ascertain their relative importance. The design team then established a function tree and conciliation between the function tree and the needs was used to draw the specifications. Conceptual solutions were then proposed systematically and Morphological Analysis was used to structure the thought process. Three different design concepts were proposed. Hand sketches followed by dimensioned CAD drawings and 3D modelling were produced and carefully discussed for each design extracting the pros and cons of each design.

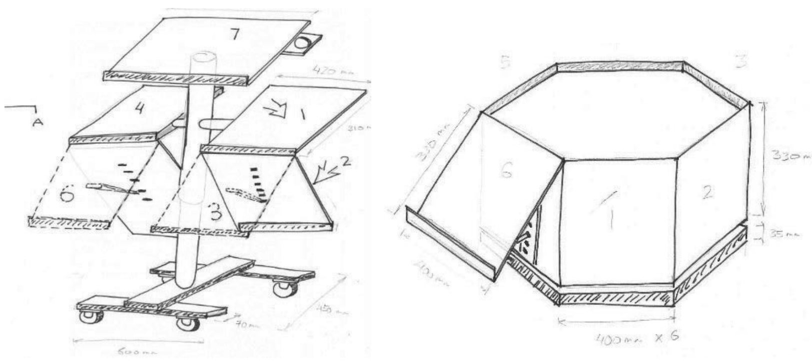

Figure 1. Hand Sketches of some proposed designs

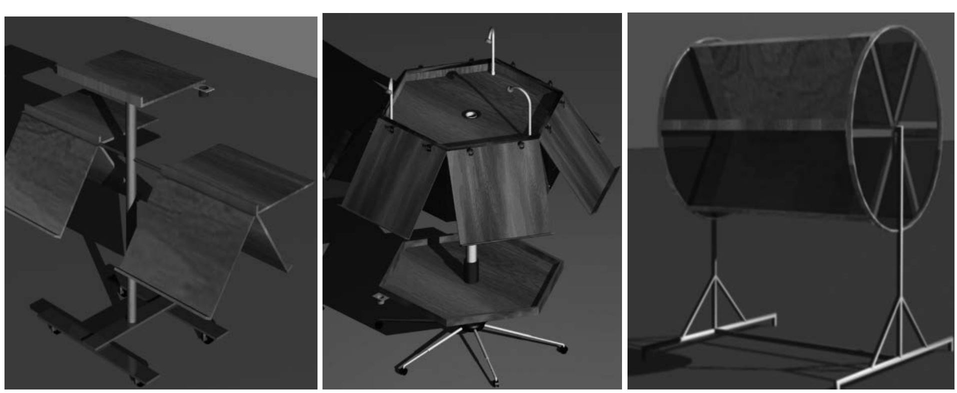

Figure 2. 3D modelling of proposed designs

Most preferable design was chosen based on SCREENING/SCORING method. The process then proceeded to the embodiment design stage. In this stage the Parts tree was established, Make/Buy decisions were carried out and specifications for the parts to be bought were drawn. Decisions were made on the choice of material for the parts to be made. In the detail design stage the product was defined completely - including smaller individual parts and all dimensions required to make the product. AutoCAD[8] was the software used to define the detail design. The last step remaining was to prove that the design is safe and optimal by identifying and carrying out the required engineering analyses. In the case of *HEX III* stability of the designed product was the main analysis needed. The design was thoroughly checked and proven to be safe before manufacturing the product was started.

4.2 Actual Product

HEX III is a wooden hexagonal tool consisting of six adjustable angle-reading panes that can be retracted in place enabling convenient reading angle. Each of the six reading panes is equipped with page holder that kept the book open while switching to another one. The reading panes are attached to a hexagonal upper body at the centre through hinges and can rotate freely through the entire 360^o allowing quick and easy access to any book with ease. The overall reading body height is adjustable providing the reader with a unique ability to read while sitting or standing. Five mobile caster wheels that provide easy mobilization of the tool support the upper body. The caster wheels are lockable type that provides the tool with stable positioning. The tool was provided with independent freely rotating LED spotlight at the top providing the reader with better vision whenever required. Moreover, the top surface can provide significant area for the reader to take notes or write comments. The tool is intended to have a coffee cup holder in the next phase. It also will provide deck for charging mobile phone, listening to music, viewing i-Pads, and some other interesting features providing reader with most comfortable means. Figures 3 and 4 show the product.

Figure 3. General Overview of Product HEXIII

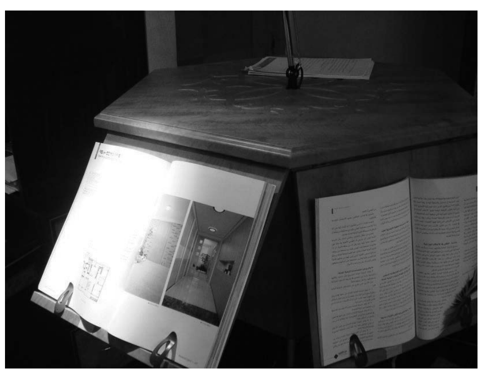

Figure 4. Multiple Books in open position.

5 EVALUATION AND THE LESSONS LEARNT

This section evaluates the work and then describes learning outcomes and learning experience of the students. The product chosen was new but there was no technical difficulty in understanding the product irrespective of the undergraduate educational background of the students. This careful choice of the project made it easy for the students to fully engage and contribute from the beginning. The design process including the design models and design methods were covered in lectures prior to the introduction of the project and it was a smooth transition from a passive listening and grasping to active using what has been learnt and, searching and finding further knowledge and information that are needed to do a good work on the product. The group of students used to meet regularly to edit, measure, calculate and discuss different design parameters during the short period of the course, which lasted for only eight weeks. In hindsight, it can be seen that this had developed the overwhelming intention to steer the project into success. The project itself was a challenge needed to be overcome which in-turn raised the sense of responsibility in all participating students to produce the best that everyone can add. The different groups of students had dramatically enjoyed manufacturing the product relying on their own technical experience they had gained during the undergraduate technical workshops courses. Nevertheless, groups met some challenges they believe had suppressed the efficiency of the overall project; for example, the planned period of the course was too short and congested to accomplish the required tasks in less than eight weeks. This resulted in eliminating some interesting features that was planned to be included in their tool. The lack of material, tools and equipment required to manufacture the product internally had resulted in coordinating with outsourced suppliers and workshops to carry out certain parts of the tool. The team lacked a professional ability to design the model in animated 3D, which was planned at the early stage. Conflicts in students prospective and roles was inevitable but was absorbed effectively after a team leader had been assigned within the group who could run the process and steer the team to a common-base. The work had met with rises and falls which were successfully overtaken only after cooperation between all team members and their faith and belief in their product to be eventually a success. The students believe that they have fully accomplished the objective of the project and the tool had reached a successful industrial opportunity.

5.1 Learning Outcomes

At the end of project assessment, the entire class had informal gathering and chat. The general consensus was that course had provided us the first hand-on knowledge and experience in the systematic process of design and product development. The learning outcomes from the students' point of view can be grouped into two categories (i) design specific and (ii) transferable skills as outlined below:

Design specific outcomes include

- Comprehending the different stages of design process, which have to be fulfilled regardless of 'what the product being designed', was. Systematic design process has been instilled as a fundamental concept in the students' minds.
- Development of a habit of focusing on all surrounding tools, machines and equipment to see if they can develop the current product for better use and smarter utilization as a life-experience, is a lasting outcome of this course.
- Learning the art of brainstorming as one effective method for troubleshooting and problem solving.
- Realizing how the engineering science learnt in the undergraduate studies can be put into action in general and specifically learning the principles of stability[7] calculations and how to stabilize any object under different load conditions.
- Learning how to set target and final specifications of any product design.
- Learning the general operations of AutoCAD and 3D Max as a secondary benefit.

Transferable skills based out comes include

- Learning the art of professional technical reports writing, negotiation, supporting arguments, paragraphs and assignments writing methodologies.
- Team leadership, roles distribution and team spirit were the essential skills gained through the learning experience of this project.
- Learning to work in harmony and collaboration; the students learnt how to deal, interact, discuss, negotiate, respect and effectively share views and opinions while thriving for the best answer to design needs.
- Learning how to hold effective self-driven meetings and how to invest the short available time to come up with a considerable achievement.

- Learning how to cooperate between team members and how to discover the strengths of each member to complete given tasks effectively which had been reflected in overall work integration as per very short time frame and huge load schedule set at the beginning.

5.2 Learning Experience

At the beginning, when the project was announced, groups of students were sceptical about being able to steer the project into a successful end. The fear and suspicion was enormous; bewilderment was more frequent but, nevertheless there was a dominating faithful intention in everybody's mind to play his/her role effectively. The amount of courage and trust that had been given to students by the professor was tremendous and he dramatically helped in overcoming many challenges met at the early stages. The group of students spent many sleepless nights working hard on their project in patience amidst of work and family commitments. They were confident that by doing so they would steer the project into a success. They learnt the art of Brainstorming, Coordination, Cooperation and Integration between each other. They learnt how to control Conflicts, Anger-Management and Tolerance. Time Management was an essential life-experience they learnt which affected their personal and career life positively. Every interim achievement was giving lot of confidence. On top of all these a lasting confidence and self-belief that each member of the team can embark on a new design project and steer it towards a successful completion was getting built.

6 CONCLUSIONS

The team members learnt the systematic design process and its constituent components the design models and design methods. Their knowledge was consolidated by the applications of the knowledge in the development of a reading assistant called *HEXIII*. In the process the students have learnt many practical lessons. The experience has given the team members confidence and self-belief that they can lead and manage product development projects. They were satisfied that their product meets the customers' requirement with which they started. In addition they are positive that their design is unique and can succeed in the market.

As a concluding remark, it can be said that working on a Product from concept to conclusion reinforces the theory taught in a more emphatic way.

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WRITING A PHD IN DESIGN AND KNOWLEDGE TRANSFER - INTERDISCIPLINARY DESIGN EDUCATION (CASE STUDY TEXTILE ENGINEERING + DESIGN)

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ABSTRACT
The structure of European doctoral programs in design with international comparison in cooperation programs is focused on creating a structured program for a PhD in design with international academic status. In Germany we saw the interest in writing a PhD in design and the role of design theory and research increasing in the last decade. In case of product design or industrial design, the typical way of engineering is demonstrated by the departments of mechanical engineering. In the last years the interdisciplinary way of working together with designers, engineers, artists, and consumers on technical solutions of the digital world and in the way of creative processing has increased in an enormous number of projects. Product engineering is related to textile educational programs in engineering + design as demonstrated in the following.
Smart technologies and smart textiles are more and more linked together in a wider interdisciplinary way of designing, which invites taking a closer look at the question: where do we come from in the field of education of designers? We present interdisciplinary design education in different design fields and with different levels of student BA- and MA-programs. We want to argue for the necessity of PhD programs to be offered at universities, in cooperation with companies to bring knowledge transfer in design to a higher level: intercultural and inter-generational (textile) design education with integrated engineer courses.

Keywords: PhD and doctoral in design, interdisciplinary academic education in EU, transfer in inter-generational education, textile engineering + design, interactive and intercultural design programs.

1 INTRODUCTION

The structure of European doctoral programs in design in international comparison is the aim of creating a structured program for a PhD in design with international academic status. In Germany writing a PhD in design does not have a long tradition, but in the last decade we saw the role of design theory and research increasing [cf.1], and a demand for marrying the sciences and arts/design [cf.2], as a basis for establishing comparable doctoral programs in design in Europe as consequence of the Bologna Process, arises. It is our aim to create smart and sustainable design solutions with the help of design research as part of a European doctoral program together with other European partners. As a consequence, we will take benefit in connecting the European Higher Education Area with the European Research Area to strengthen international cooperation between universities and institutions with the Lisbon Strategy goal of making the EU the most competitive economy in the world [cf.3]. With the help of case studies from interdisciplinary projects in the case of textile engineering + design, e.g. "sustainable textile design" and "smart sustainable solutions connecting people − the German Look compared to other national perspectives" − we present interdisciplinary design education in different design fields and with different levels of student BA- and MA-programs. We want to argue for the necessity of PhD programs to be offered at universities, in cooperation with companies (industry + engineering + design) to bring knowledge transfer in design to a higher level: intercultural and inter-generational design education with integrated engineer courses. An earlier design thinking of children and young people is necessary and would mean that design education should be taught at an earlier stage at secondary and primary schools to circularise design thinking.

2 PRODUCT ENGINEERING + DESIGN IN CASE OF TEXTILE ENGINEERING + DESIGN

Smart technologies and smart textiles are more and more linked together in a wider interdisciplinary way of designing, which allows a look at the question: where do we come from in the field of education of designers? In case of product design or industrial design (older term, which is not anymore as common at modern universities to express an innovative mind set) the typical way of engineering is demonstrated by the departments of mechanical engineering. In the last years the interdisciplinary way of working together with designers, engineers, artists, and consumers for technical solutions of the digital world and in the way of creative processing, education came into focus: an overall interdisciplinary and interactive designing [cf. 4]. The education system in Germany is a federally-defined system – but more important is the cultural impact of working in one discipline and the high level of product quality characterised by the "Made in Germany"-icon. This applies not only to a high standard in engineering programs and the following long tradition of engineering studies education.

Within the former education in Germany, people were trained in a classical manner to learn **one** specification. In case of industrial design, the impact of engineering courses stood in relationship to the practice-based experiences of the professors, because they also defined the curriculum of the study programs. In the last years two other aspects have come into focus to define new structures for the curriculum. First: the Bologna Process has had more influence in a comparable way, how to create the study programs of one discipline in one country, that the students could work around the world in a "globalized" pattern. Second: several institutions have come into being to shape internationally or nationally comparable structures – the unique features of the study programs are only a question of terms and expressions of ONE University to demonstrate and communicate the profile – a profile different to other universities. At the Hochschule Niederrhein - University of Applied Sciences, we have ten faculties, and Faculty 07 – Textile and Clothing Technology is the oldest one, existing for more than 100 years with a long tradition of applied textile education and cooperation with textile industries. The need of textile experts for the so-called "Manchester of the Lower Rhine" 100 years ago, formed the textile-engineering-based education. Now, at the beginning of the 21.st century we know that the scientific and practice-based education needs the creative industry, and, at the same time, the creative mind set in a manner of research as a consequence of BAUHAUS the "artistic research" included as part of our BA and MA programs in design. We have to look at other disciplines – from engineering to sociology – to take benefit from smart and sustainable solutions for design applications for today as well as for the future generations.

The following designs and design research studies will give an insight into textile design education[1] in Germany and as a part of that advanced studies in master programs in an intercultural manner like design thinking and fashion thinking for the future.

3 TEXTILE ENGINEERING + DESIGN-EDUCATION IN INTER- AND TRANSDISCIPLINARY WAYS – WITH SPECIFICATIONS

The overall topic of the interdisciplinary project "The German Look at Design − advanced TEXTILE solutions", which is presented in 2015 in different venues, will show a collection of several Bachelor (BA)- and Master (MA)-student projects and research works of MA students, with the following topics:

I. Smart Textile and Mobility in Fashion: SMART FASHION – "creative processing" II. Luxury and sustainability: "White World" III. Design concepts...for a better world IV. Textile Porcelain V. Smart mobility to go VI. Kids World − (textile) patterns connecting generations.

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[1] http://www.hs-niederrhein.de/textil-bekleidungstechnik/projektestudienarbeiten/fb07-german-look/


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Figure 1. clever kids crocheting, by J. Jandoo. Figure 2. deployable interaction, by L. Kisser, 2015

The challenge for the students lies in defining the typical character of each cultural design code in combination with discussing the terms ”Luxury" and ”Mobility", ”Sustainability" and ”Smart Textile", for example, in fashion AND automotive interior design for advanced design solutions for tomorrow. Forecasting trends in smart textiles, like the currently discussed terms about ”Biocouture" [cf. 5] and – so to speak −“Green Smarts" [6], are only two small aspects of research projects in a new material world. ”Upside downing" in up-cycling design and redesign of handcraft techniques demonstrate the range of parameters regarding sustainability. With the look at the German style and, for example, in comparison to Scottish or Italian fashion design codes or with the craftsman's knowledge, we will demonstrate ”The German Look" in connecting cultural heritage of fashion design and handcraft power with 3-D techniques. This means that the case study automotive design on a higher level of education combined with creating textiles samples for fashion design **at the same time** shows the complexity for designing: sustainable + smart textiles surfaces, for example, for kids outfits + automotive interior applications. Look at the following studies of a selection of master research projects and master theses:
The following case studies are the results of an engineering-based textile design education, in which the students had the opportunity to work in a wide range of laboratories, doing research in different branches and at scientific -based congresses:
The upcycled jeans for the couture dress “sunshine & starglow” (cf. fig. 3) by Kathrin Erge, will be lightening up with the help of a LED-structure and a solar panel at the shoulder, which collect the energy by day for shining by night.
The smart and sustainable design in “Smart Bionics” (cf. fig. 4) by Lara Leetz shows biomimetics in fashion design + automotive interior design.

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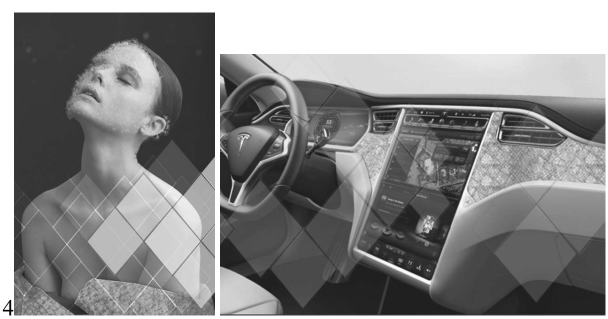


Figure 3. Sunshine & Starglow, by K. Erge, Figure 4. Smart Bionics, Design L. Leetz, 2015

Smart textile solutions for the automotive interior design for Tesla like “smart bionics”, the surface texture of fish scales and their mechanical properties are transferred by simulation of a multi-layer leather hybrid: “Haute Tech” is quilted with an electrically-conductive yarn with photovoltaic properties, for fashion design and at the same time for automotive interior applications.
A different example of dichromatism in fashion design like smart bionics is shown by the interesting topic of a design by Philipp Trosien: “Mimesis, a fashion design strategy – nature’s creations and it’s

values, case study camouflage“ (cf. fig. 5). Biomimetics describe − analogous to mimesis in nature − a creative evolution that reinvents the archetype nature. The results are ‘disruptive patterns‘ which make it impossible for human perception to differentiate between figure and ground. The concealment of the own identity inspired by nature can be seen as an interdisciplinary approach of bionics respectively biomimetics.

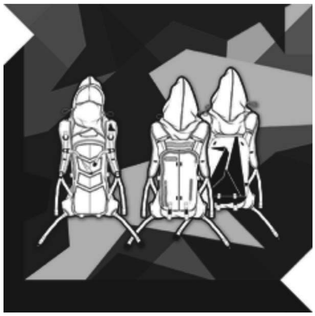
5 
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Figure 5. Mimesis, a fashion design strategy, Trosien; Figure 6. Lustgund by M. Adler, 2014

Beside this natural and graphically-inspired design management for fashion, the prototyping of low volume production for sustainable luxury goods is demonstrated by the textile porcelain: “Lustgrund” (cf. fig. 6) created by Miriam Adler. The cradle of textile “manufacturing”, to make bobbin laces, is transferred into a new material. The combination of manufacturing and engineering knowledge will generate ideas for new applications in the materials sciences for design, like it is shown by kiln [cf. 7] and new combinations in nanotechnology [cf. 8].
Another example of connecting people and generations with the textile heritage or with the knowledge of textile manufacturing is the project by Jennifer Jandoo: “German kids clever against darkness” (cf. fig. 1) is a four months project by product developer Jandoo in cooperation with Dr. Marina-Elena Wachs, implemented at Jakobus Elementary School in Grevenbroich/Germany. Promoting handicraft, the project allows children to craft crochet hats with a fluorescent surface reflecting light when illuminated. In the context of crocheting, the objective of this project is the approach of a sustainable cultural and linguistic education by means of obtaining textile manual skills. Jennifer Jandoo chose to work with elementary school pupils to introduce the concept of an early education of motor skills using design within society at an early stage. Furthermore, counteracting the loss of traditional (textile) handicraft due to a generation change was utterly significant in this project. Both cultural and regional historical heritage of handicraft techniques were conveyed. These are the bases of an early touch of textile competence for the textile experts we need in the future [cf. 9].
The project demonstrates the possibility to touch textile history for the textiles future as well as to gain social and linguistic competence. At the same time it generates “abstract thinking”, necessary to understand artificial concepts of the future, and at the end of the educational process to be able to do “research in design thinking” [cf. 10]. It also displays the changing world on both sides of analogous and digital processes.

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Figure 7. Fashion Thinking, by L. Witt, Figure 8. IQ-Leather: travellum bag by V. Winkelmann, bag and sketch, 2015

The excellent MA study of "Fashion Thinking" (cf. fig7) by Laura Marie Witt shows the combination of product engineering and textile engineering in the master program education for the next level of a fashion-minded development [cf.11] in combining the fashion system with augmented (engineered) reality [cf.12]. It shows an exchange of medial textile gadgets in an individual personalized style for the owner of the outfit. At the same time it exposes the complex process of the digital future society and a textile solution to protect oneself against the body scanning of privacy.

4 CONCLUSION: INTERCULTURAL, INTERGENERATIONAL AND INTERDISCIPLINARY EDUCATION FOR SCIENTIFIC RESEARCH IN DESIGN

With the help of knowledge transfer in cooperation design projects in an interdisciplinary education style, working on one topic on different education levels, the BA- and MA- students and graduate students take advantage of transdisciplinary learning platforms in design. We have to focus on two challenges of the doctoral programs in design: first there is the acceptance by other disciplines, which have been established for quite some time, to discuss on the same level [cf.13] and to design together [cf.14]. The second challenge is based in the term "artistic research" in relationship to the applied sciences. EARN (the European Artistic Research Network) was established in the year 2004, with the aim to exchange research knowledge and experiences. But for the future we need to integrate experts' knowledge with the help of cooperation projects of graduates [cf.15], universities and companies for knowledge transfer in design on a higher educational level: intercultural and inter-generational design education. A result of education in primary schools at an earlier stage should be to encounter the textile manufactured and engineered heritage as this is required to be a textile expert one day. The fundamentals are to think about the next generations of textile products and to generate the next generation of textile experts with the help of an engineering-based design education in combination with enough space for artificial creativity and research vice versa: art takes benefit from engineers' knowledge like design takes benefit from engineers' knowledge.

The creative industries have a great scientific and economic impact on all branches: fashion and product design, automotive industries, interior architecture, architecture, art, theatre and other. The research study of "IQ-Leather – light lines in leather design for >BLUE Luminous< design concept", the travellum bag" (cf. fig. 8) by master student Verena Winkelmann shows the complexity of applied engineer know how as designer: to fold the bag in a linear structure inspired by the form of the star, the icon of Mercedes Benz in a sustainable vegetable tanned eco-leather and by lightning by night with the help of nature-based luminescent colours. The lines are constructed in the structure and pattern of the travellum bag, inspired by a free linear interpretation of the star.

Formal Inspiration – Design Process – Research in Materials Sciences – Engineer Process (for the prototype) – Users interest in focus, these are the process parameters for the textile engineering + design creation, for smart and sustainable textile products for the future. These are the parameters for textile engineering + design education.

It is our aim to create smart and sustainable design solutions with the help of design research as part of a European doctoral program together with other European partners. As a consequence we will take benefit in connecting the European Higher Education Area with the European Research Area to strengthen international cooperation between universities and institutions with the Lisbon Strategy goal of making the EU the most competitive economy in the world [cf.16]. The first steps are done with interdisciplinary design programs in small projects at the university in transfer to greater socially-relevant topics, created and discussed at the expositions and events with each other – with experts and with the civilian population.

The next level is to fix standards within the curriculum and to make exchange programs around these projects/topics possible together with students of European universities – with financial European support – for investment in European cultural education. Intercultural graduate programs can be realised. We have to consider both: exchange of smart and sustainable textile statements in an intercultural and – so to speak – inter-generational way on every student's level and, at the same time, to initiate textile competence and design on an earlier educational level than we do today at school. Touching textile heritage in transfer of textile-engineering knowledge on different educational levels is needed to serve and to provide next generation textile experts in design + engineering.

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Chapter 11

Design Teaching Methods

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
3 & 4 SEPTEMBER 2015, LOUGHBOROUGH UNIVERSITY, DESIGN SCHOOL, LOUGHBOROUGH, UK

SAND CASTING ON THE BEACH - INTRODUCING TRADITIONAL MAKING SKILLS, MATERIALS AND PROCESS THROUGH PLAY AND EXPERIMENTATION

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[1]Oslo and Akershus University College of Applied Sciences
[2]School of Arts and Creative Industries Edinburgh Napier University

ABSTRACT
Within the higher education (HE) product design field, many researchers stress the importance for students to recognise and value the relationship between practical 3D object-making experience, and experimenting with process and materials. Given the increasing pressures for design departments to sustain and keep large workshops, we face the perhaps inevitable consequence that product design students will lose fundamental physical 3D-object making skills. A case study from a sand casting workshop was used to investigate how new learning spaces could develop a teaching methodology to teach material and production knowledge, using low budget, low-tech, and practical object-making methods. The study showed that this learning space engaged the participants with the project and developed insights into teaching and learning that would not have been achieved through purely theoretical, studio-based teaching. Furthermore the workshop created an arena for social and professional interactions, and was found to be a possible tool for a discourse on sustainable design and production. The study led to developments in the design curricula of the participating institutions and resulted in learning outcomes of relevance for product design education.

Keywords: Crafts, learning spaces, international collaboration, ecology, material experimentation.

1 INTRODUCTION

There is increasing concern within the HE product design community that teaching traditional object-making skills and material experimentation is decreasing [1]. One example is Bucks New University in London, which is closing its renowned undergraduate programmes in furniture design. Neil Austin, head of the furniture design course, said, *'Creative courses are a little bit messy and a little bit big—they need workshops, they need facilities and they need space to play'* [2]. This issue was echoed by Apple's chief designer, Jonathan Ive, who spoke recently at the Design Museum in London: *'So many of the designers that we interview don't know how to make stuff, because workshops in design schools are expensive and computers are cheaper ... that's just tragic, that you can spend four years of your life studying the design of three dimensional objects and not make one'* [3]. In addition, there is a lack of skilled teachers in lower education [4]. In Norway, 70 percent of the educators teaching arts and crafts under the age of 30 have no formal education in an art or design discipline. This has alarming consequences for staff recruitment into design at HE institutions, and impacts on the lack of practical object-making skills that students acquire while attending HE institutions.

Traditional object-making processes serve to develop principles and disciplines from which students are empowered to explore and engage with new object-making technologies. At a time when our digital tools allow for more work to be processed virtually, the traditional workshop can complement the development of the digital learning environment. This competence is important for new product design graduates who will face the challenges of working in industry once they graduate. Students should not need to rely on having access to large, well-equipped workshops in order to gain experience with hands-on object-making and experimenting with materials.

2 BACKGROUND

Several researchers have emphasised the importance of hands-on experience and the connection between crafts and process [1, 5, 6]. This is not a new opinion, and is in fact something Aristotle thought about: *'Lack of experience diminishes our power of taking a comprehensive view of the admitted facts. Hence those who dwell in intimate association with nature and its phenomena are more able to lay down principles such as to admit of a wide and coherent development; while those whom devotion to abstract discussions has rendered unobservant of facts are too ready to dogmatize on the basis of a few observations'* [1].

A more recent commentator is Deputy Head of Research and Head of Graduate Studies at the Victoria and Albert Museum, Glenn Adamson [5], who, in his book *Thinking through Craft*, views object-making and experience with materials as a craft and process that should be regarded as a habit of action rather than a fixed set of things. *'Craft is not only a way of making things, but a way of making people: a means of social improvement.'* This approach corresponds with the writings of John Dewey and the theories of the progressive educational movement from the late nineteenth century [7, 8]. Dewey defined *experience* as a moment of interaction with objects and processes. Through engaging with these processes, students are offered opportunities to develop, and to grow their pride and self-esteem; these processes also promote mental and physical wellbeing. These building blocks could inspire students and empower education to not only build strong economies but also sound societies [5]. This view proposes that the interaction with objects and processes become more than just making objects, which aligns with the work of the American sociologist Richard Sennett [6], who views craft in this broader sense. He argues that the physical making of objects is part of being human, whether it involves making objects, food, or music. He suggests that physically making objects is needed to provide a balance from an increasing culture of screen-based mental processing tasks, both at work and at home. This could indicate that the increasing pace of learning, the easy access to information offered in the digital realm, and deadline-driven processes are having an effect on opportunities for students to reflect on their learning during projects.

The demise of physical workshop facilities within design education is a growing concern for many. Mathew B. Crawford [1], an American writer and researcher in cultural studies, champions the need and recognition for intuitive and tacit knowledge, stressing the negative effects that the decreasing workshop facilities within US design education has had on this knowledge. Without the opportunity to gain experience in physical object-making, Crawford argues that most forms of real knowledge, including self-knowledge, come from the effort to struggle with and master the reality of material objects. This corresponds to a large extent with the theories of Adamson and Sennett [5, 6]. Crawford further argues that the ideologists of the knowledge economy have posited a false dichotomy between 'knowing' and 'doing'. The importance of doing is emphasised by the arts and design writer and critic, Peter Dormer, who stated, *'the constructive rules of craft are only learned by actually doing the activity'* [9]. In 2006, the designer Max Lamb made his 'Pewter Stool' [10], manufactured from a sand-casting process produced on a beach. This was a low-tech manufacturing approach with a minimum need for tools. The project showed that experience with some crafts and processes can be achieved without the need to have access to well-equipped workshops. From a design education perspective, Lamb's work is interesting to us because it addresses different learning spaces. Setola et al. [11] use the metaphors the wild, the pub, the attic, and the workplace to visualise and emphasise the importance of different learning spaces through the learning journey. This view suggests that different learning spaces will support and encourage different learning experiences.

2.1 Research Question

From a design pedagogy perspective, it is interesting to use learning spaces creatively and to observe the impact that this might have on teaching and learning. Learning spaces are frequently discussed in design research, but there seems to be little focus on how the use of an outdoor environment might influence the learning outcomes within the context of teaching material and process. This led to the following research question: How to develop new learning spaces to teach material and production knowledge and skills, using a low budget, low-tech, physical object-making process?

3 METHOD

The main research method is a case study [12] of a two-day 'design and make' jewellery workshop conducted in Edinburgh, Scotland. Participatory observation [13] was used to study how students were responding to this playful and simple project structure, which emphasised practical experience with materials and process. An eco-philosophical perspective [14] was used to discuss the impact on environmental sustainability this method can have on the learning process.

3.1 The sand casting workshop

The workshop was developed through an established Norwegian/Scottish research and teaching collaboration. Thirty product design students and five teaching staff, representing both Scotland and Norway, participated in the workshop; we were also joined by a local professional sand casting company. We structured the workshop around a 'lost Styrofoam' casting process. Day one of the workshop was conducted indoors, in the university's studio space. Students were asked to make jewellery models out of Styrofoam, which they sourced from discarded packaging materials. On day two, the project workshop relocated to a local beach (Figure2). The Styrofoam models were dug into the sand, leaving one part of the model emerging above the surface of the sand (Figure 3). The attendees built a fire from driftwood found on the beach to melt pewter. The melted metal was poured onto the Styrofoam, melting and replacing it to create a perfectly matched cast. The cast artefact was then dug out of the sand and cooled in the sea. We also experimented with aluminium casting, which required using propane as a heat source rather than the fire due to the higher melting point of the material. Part of the finishing work on the casts was done on-site, but the unpredictability of the outdoor environment meant a trip back to the university to complete the rest of the projects.

4 FINDINGS

The workshop produced a wide range of findings, ranging from observations on individual skills acquisition, to impacts on the larger group dynamic. Students were noticeably more engaged in the process compared to similar workshop themes that were conducted in the studio. Using an outdoor teaching environment not only excited the students, but also led some to experiment in ways that may not have happened in a school workshop. For example, some students started to cast into patterns that they carved into the sand, while others cast directly into shells and similar objects that they found on the beach, which created some unexpected outcomes. Students clearly gained new insights into working with materials and a craft process. Many had difficulty understanding the transformation from Styrofoam to metal, and how that affects issues such as dimension and weight in a jewellery piece. Also, most students became obsessed with 'finishing' their jewellery, grinding away any perceived imperfections in the casts and leaving few traces of the making process.

The workshop also created an environment that encouraged social and professional interactions, which probably developed more easily and quickly because we were away from the more formal structures of studio- and office-based locations. The beach acted as a hub, bringing together representatives from two nations and participants from both industry and academia, as well as inviting the interest of inquisitive passers-by. Ideas generated as a result of the workshop were noted as opportunities to discuss and make changes to both university's respective product design curricula. In addition, the findings also indicated that similar workshops could be used as a platform to develop a discourse about environmental sustainability.

5 DISCUSSION

The aforementioned sand casted Pewter Stool [10] by Max Lamb, which he produced at Caerhays Beach in Cornwall, UK, provided a source of inspiration for developing this workshop. Lamb's technique, however, differs from the main method used in this workshop. He dug directly into the sand to create the casting mould and used propane as a heat source, while this project primarily used 'lost Styrofoam' casting and an ordinary outdoor fire for melting the metal. Despite these process differences, both methods are similar regarding the use of the beach as a studio and production space. Lamb's video post [15] of his manufacturing process provided both a source of inspiration for our students and a context for the workshop. In particular, Lamb's work helped to demystify the casting process and manufacturing techniques for students who were engaged in design processes with the workshop for the first time.

5.1 Student engagement and learning spaces

Students were noticeably more engaged in the process compared to students' participation in similar workshop themes delivered in-studio. Of particular note was student attendance. All students arrived on time at a cold, rainy, and windy beach on an October morning, 4km outside of the city centre. This is a strong indication of student engagement if we compare this to the late arrivals or absences that generally occur during studio-based modules. Students actively took ownership of their own learning; they did not want to stop the workshop, even given the challenging weather conditions. They wanted to organise future workshops through independent study, if it were not possible through the university. Dewey emphasised that through engaging with processes we are offered opportunities to develop, and to grow our pride and self-esteem; these processes also promote mental and physical wellbeing [7, 8]. To what extent this workshop achieved this is hard to measure, but the engagement from the participants was obvious. We could clearly spot both pride in their work and healthy self-esteem amongst the students upon completion of the various tasks.

Figure 1. Experimentation

Figure 2. Sand casting

Figure 3. Lost Styrofoam

The natural restrictions imposed on the workshop (by time, weather, and light) focussed the project towards process-driven experiences rather than final project outcomes. Removing the expectation of a 'finished' project outcome likely freed the students to experiment and to make mistakes without the perceived risk of failure. Whilst care was taken to decrease risk from the workshop, the nature of the materials and process required an element of working with risk. In this context, risk was regarded as the control the students had over the processes and the impact on the outcome as a direct result of their object-making skills. The casting process was quite unforgiving, as there was no option to press undo or to reach for a rubber. The students were encouraged to work with their 'happy accidents' and unexpected outcomes.

Furthermore, we observed an interesting mind-set in most of the students. Nearly all were concerned with creating a smooth, blemish-free finish to their objects. On reflection, this should not have been such a surprise, given the desire some students have to create attractive CAD visuals, aided by sophisticated rendering packages. This gave the teaching staff an opportunity to discuss with the students the possibilities of working with some of the random outcomes this casting process can offer, and not to erase the provenance of the object.

In addition, several of the students had difficulty predicting the outcomes of the different stages of the project process. For example, Styrofoam is an extremely lightweight material, and what is perceived as a logical size and scale for jewellery (when modelled in Styrofoam) might not be appropriate after it is cast in pewter. Students were told about these issues prior to modelling their designs, thereby gaining theoretical knowledge; at that stage, however, they did not yet have practical experience. This indicates that the change in appearance from one material to another is something one has to physically experience in order to successfully develop and control successive processes and production of objects. This example shows how skills acquired through hands-on experience is important for gaining material understanding. Furthermore it corresponds with the work of Sennett [6], who emphasises the importance of the close connection between the hand and the head, and views this as a dialog between a concrete practice and a way of thinking, which can evolve into discovering and solving problems. The practical, hands-on nature of the workshop required the students to continually wait and reflect on their tasks before moving on to the next step of the object-making process. This allowed students and staff time to discuss the progress of each project, and contributed to developing a holistic approach to the teaching and learning environment.

Looking at Setola's [11] thoughts on different learning spaces for different activities, it seems that the beach learning space affected the learning outcome differently than if the workshop had occurred in a school workshop. For example, students experimented with casting into found objects on the beach (Figure 1). A more unexpected example was the experience students had when they discovered a washed-up beam in a container near the beach. Students wanted to use this for their fire, but were surprised to discover the beam's high density. It was so heavy that it required four people to carry it, while two people could easily carry a similarly sized beam of Norwegian spruce. In addition, they discovered the difficulties of cutting this hard wood and getting it to burn. These experiences would not have occurred through teaching from a purely theoretical and studio-based perspective. According to Dormer [9] and Crawford [1], these types of skills and knowledge are best learned through experience.

5.2 Social and professional interactions

The location and preparation of the workshop site needed careful planning from the staff, which required a number of visits to the site, working around tide times, Scotland's unpredictable weather forecasts, and access to the site for transporting materials. This extra-curricular activity proved to be a positive experience for the dynamics between the academic staff and the industry participants prior to the workshop, most of whom had not met each other previously. During the course of the day the site needed to be prepared, maintained, and dismantled, which were tasks that required collaboration between all participants; this promoted inclusive and equitable interactions between staff and students. To encourage a good interaction with curious onlookers, it was important that we did not damage the beach; we needed to demonstrate that we were working safely and responsibly.

An additional goal for the workshop was to further develop our existing international relationship by including industrial collaboration. An Edinburgh-based 'green' sand casting foundry was invited to collaborate with us on the beach casting day. We were pleasantly surprised to hear that they gained new knowledge from the process, as well, and remarked throughout the day about some of the processes and techniques that *'they had not realised you could do this'*. In addition, the company contributed skills and knowledge, becoming both learner and teacher. Some staff members were also new to this particular object-making process, so they became learners alongside the students; this forged a sense of camaraderie among all participants. This was a particularly rewarding example of developing a holistic learning experience.

One outcome from the workshop is that it has led to a discourse on workshop activity at the Norwegian University College. This discourse may lead to the implementation of several one- or two-day, material-based elective courses. Similarly, the experience of the workshop has led to proposals to restructure some module content on the product design programme at Edinburgh Napier University.

5.3 Contributions to a sustainability discourse

The workshop can contribute to a sustainability discourse. One way of discussing this is through Arne Næss' theory on 'deep ecology' [14]. Through his ideas on complexity, Næss claimed that mature and stable ecosystems are characterised by great inventiveness and the multiple uses of resources, and that every society has alternative ways to satisfy its needs: if one factor reduces the possibilities, there are alternatives within the local community. The process of casting in the sand of the beach is an example of seizing other possibilities within the community when workshops aren't available. The concept of deep ecology is interesting from a design perspective, because it emphasises the importance of relational thinking, holistic thinking and system thinking. These are all factors of importance within a holistic design perception. In deep ecology, everything is connected with everything else through a mutual, dependent relationship in a long-term perspective. It is a symbiosis, where all parties extract mutual benefits from each other through true companionship. In this workshop we used natural resources like sand, water, and wood found on the beach. The materials used for making models were discarded Styrofoam retrieved from the garbage. It was important to leave the beach unspoiled after use. This can be an important contribution to relational and sustainable thinking in design education. It is a way of experiencing a holistic, ecological praxis first-hand.

6 CONCLUSION

One of the aims of this study was to develop a learning environment though hands-on experience with a physical object-making process. Sand casting on the beach proved to be a low-budget and low resource approach to hands-on learning and teaching experience, with a focus on working with materials and process. This working methodology encouraged collaboration between students, academics, and practitioners, and inspired future, student-led learning events. Furthermore, it will likely lead to curricular changes in both of the participating institutions. The study indicates that traditional object-making skills still have a value and place alongside digital, 3D prototyping technologies and theoretical teaching. In addition, the method aims towards viewing the diversity of learning spaces, and how these spaces can lead to different learning outcomes. This outdoor learning space created an opportunity for experimentation, insight, and learning which would not have been possible in a school workshop. Using natural resources like driftwood, sand, and water, and the opportunity to leave the working space unspoiled once the project was complete, made it possible to view the workshop through the perspective of environmental sustainability. The extent to which the students experienced insight into the relative sustainability or unsustainability of our workshop is unclear. It is plausible, however, that this approach could be used in a sustainable design discourse.

The learning outcomes identified [16] in this study are relevant issues in product design education concerning knowledge, skills, and general competence. Having knowledge is to understand the importance of material knowledge in product development. Skills are related to process understanding and the skilful manipulation of materials. From a sustainability perspective, general competence is to see nature and design as mutually corresponding elements. This case study is based on a single workshop, but the phenomena identified has the potential to stimulate and foster similar outdoor object-making workshops. For future workshops it would be interesting to think about how to integrate the planning and logistics of organising the outdoor workspace itself, as a specific learning outcome for the students. For other design educations who wish to explore these possibilities, it does not have to be casting. Trough trying out different learning environments, using crafts, delivering short workshops and engaging with materials and play with a range of physical 3D making skills, we presume you will reach similar results.

The workshop offered learning methodologies in addition to the chance to observe, listen, and physically engage with a process. It also provided opportunities to experience tacit knowledge, and required collaboration between all of its participants, each having a responsibility for one another and for the environment. In addition, lecturers, industry practitioners, and students had the opportunity to become both learner and teacher. This was a challenging and rewarding workshop and, in the words of Glenn Adamson, *'Craft, because it is hard won, is always a revelation'* [5].

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INDUSTRIAL DESIGN: A PROFESSION BETWEEN ENGINEERING AND APPLIED ART

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ABSTRACT

Competences acquired during industrial design education and competences actually required in professional design practice are sometimes diverging. This article outlines characteristics of the industrial design profession in Norway, discussing changes in the profession, different roles of the industrial designer, and skills and knowledge required. With a basis in surveys done at the Norwegian University of Science and Technology (NTNU) as well as in depth interviews of graduate industrial designers from NTNU, a set of skills, knowledge and qualifications are identified and implications for improvement of industrial design education are made.

Keywords: Industrial design education, skills, knowledge and qualifications in industrial design.

1 INTRODUCTION

Industrial design is a diverse discipline that embodies different directions within the design profession itself (i.e. design engineering, interaction design, graphic design, furniture design etc.) as well as multiple additional professional fields. As a result the curriculum of an industrial designer often reflects a large variety in content and courses. According to S. F. Liu et al. [1] industrial designers must incorporate knowledge of multiple fields, including marketing strategies, design, research and development, basic knowledge concerning production as well as integration management and communication skills. Design connects art and engineering e.g. through constructive processes, as well as aesthetics - both engineering and art utilize imagination and creativity to further explore the possible. From an educational view, Lippincott [2] signifies four basic areas of design training: Art, Engineering, Economics and Humanities [15]. Although diversity in skills and knowledge can be viewed as the strength of an industrial designer, the acquisition of abilities in these areas may pose complications. Several studies and published literature on design education also argue that there is a gap between knowledge required at school and competences required in practice [1, 3, 8, 12].

This article seeks to review competencies acquired during industrial design education in relation to competencies actually required in employment and tie this up to industrial design education. The authors analyze job market and candidate surveys from the Norwegian University of Science and Technology (NTNU) as well as in-depth interviews with practicing designers. The “Arbeidsmarkedsundersøkelsen 2010 (Job Market Query)” relates to the work situation of former students at the Department of Product Design (IPD), to what industrial designers work with after they graduate, as well as how they consider the content and relevance of the university curriculum in context of their work. The survey is part of a series that have been released biannually since 2002 (with the exception of 2012). The “IVT Kandidatundersøkelsen 2013” survey, released earlier this year (2014), has the same focus and is done by the Faculty of Engineering Science and Technology (IVT) at NTNU. The in-depth interviews were conducted with working industrial designers educated at NTNU: Two product designers, an interaction designer, an UX-service designer and a graphic designer. Based on the findings from the surveys and the interviews, the article gives recommendations for improving design education, which include emphasizing the involvement and collaboration with businesses and industry, and using working/practicing designers as mentors and supervisors for projects.

2 ROLES AND SKILLS IN THE INDUSTRIAL DESIGN PROFESSION

Industrial design's emergence as a profession can be viewed as a consequence of the industrialization in the late 19th- to the 20th century however with changes to globalization and worldwide markets and issues such as sustainable development, the designers' roles continue to differentiate. The following section gives and overview over professional roles [6].

The role of the designer as the creator refers to the designer being in full control of the design process. The inspiration and idea for the product, sketching, development and final design is all done by the designer as creator and artist behind the product. The role of the designer in a team originates from the thought of design not only being a means of product styling and aesthetics, but also a part of the product development process and part of a team consisting of different professionals such as e.g. engineers, architects, and marketing people. Today this is a fairly common way of working. The role of the designer as end-user expert comes from the necessity to understand who one is designing for. Design of products and services based on usability and the end-user has become very important in the industrial design profession. The role of the designer as a coordinator, a design manager, emerged as a result of the designer working in a team and being an end-user expert. Design management includes management of design resources in a company, but it may also include design of corporate strategy and brand experience. The role of the designer creating experiences refers to the designer being part of the overall planning scheme in a company relating to the design strategy and experience design. The designer creating experiences is about focusing on the experience for the end-user and making them connect to a brand on an emotional level. Finally, the role of the designer pushing innovation is related to design as finding new perspectives and solutions through creativity [7].

Besides 'classic' roles and skills, there are trends of industrial design practice that influences them and in turn becomes important for education as e.g. Yang et. al [4] points out. Among these is increased use of digital media due to emerging new technology, which in turn changes methods of presentation, sketching, rendering, model making and technical drawings. Further, there is an increasing need of interdisciplinary teamwork due to considerations regarding user research, lifestyle trends, social-, psychological- and ideological issues. Besides theses conceptual views of designers, what an employer looks for is a designer with proficient design skills, contextual understanding, design knowledge, planning and integration capabilities, design expression and aesthetic literacy [1, 3]. These skills are all part of what one can call a professional expertise and professional behaviour. Lewis and Bonollo mention five dimensions in characterization of a professional behaviour [8], which consist of:

1. Negotiation
2. Problem solving
3. Acceptance of responsibility
4. Interpersonal skills
5. Project management

Negotiation refers mainly to negotiation with clients, this covers task clarification as well as further negotiation with clients if the client's ideas change during the project. When talking about problem solving in the industrial design profession one can say that one talks about the design process itself since problem solving is the main goal of the design process. The design process includes concept generation, evaluation and refinement of concept, detailed design and communication of results, and finally the overall skill displayed by the execution of this design process. Acceptance of responsibility refers to acting and behaving self-ruling and independently for the outcomes of your work. Interpersonal skills refer to be able to collaborate well with colleagues and clients. Lastly, project management is about organizing and planning work as well as ensuring that goals are met throughout the course of the project.

3 RESULTS

3.1 Findings in Surveys Regarding Work-Situation amongst Graduate Industrial Designers

In this section, the most relevant findings from the survey "Arbediedsmarkedsundersøkelsen (job market query) 2010" and the survey "IVT kandidatundersøkelsen" (candidate query) are presented.

3.1.1 Arbeidsmarkedsundersøkelsen 2010

In 2010 the fifth and latest survey in series of surveys regarding the work situation of former students at the Institute of Product Design (IPD) at NTNU, "Arbeidsmarkedsundersøkelsen 2010", was conducted [9]. The survey was organized by Leonardo, the student association of IPD at NTNU. 86 out of 174 graduate students answered this survey.

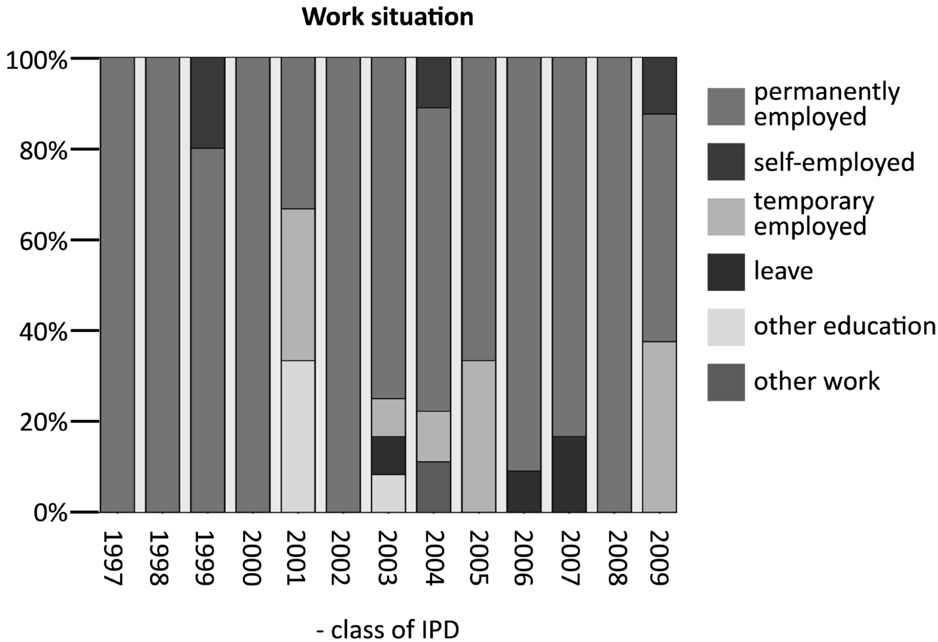

Figure 1. Work situation for graduate industrial designer at NTNU

23% of the respondents were employed in a consultancy firm, 33% were employed in industry or off-shore, 18% were employed in telecommunication, media and IT, 11% were employed in education and 15% were employed in other fields. To the question about what specialist environment they work (collaborate) with answered 85% technical, 57% economics, marked and business, 46% communication and media, 16% health, 12% social sciences and humanities, and 11% juridical. The question was asked in a way that more than one answer could be applied. On the question regarding which tasks industrial designers do as part of their work the result was as follows: about 74% do project management, about 76% make presentation material, and approximately 70% do product development. The percentage of time for tasks estimated in the 60-50% range were user-interfaces, design strategies, sketching, materials- and construction choices, counselling and interaction design. In the 50-40% range administration, aesthetic forming, graphic design, production modifications and 3D modelling. In 40-30% ergonomics, market research, physical modelling, web-design and packaging design. Below 30% were education and eco-design. On the questions about relevancy of areas and subjects from education, the results experiences from team- and group work and the design related subjects were rated very important. Other important subjects were scientific subjects (mathematics, physics etc.), design strategies, human-machine subjects and form and colour subjects. Furthermore, system design, ergonomics, communications, It-subjects and subjects regarding management were rated fairly important. Workshop work, organizational work, and economics were rated less important. Mechatronics and eco-design was rated least important. Evaluating learned methods of work, both single work and in group work were rated very good. Self-study and projects in pairs were rated good, while lectures and exercises were rated least good for learning.

3.1.2. “IVT kandidatundersøkelsen 2013”

In 2014 the results from the survey “IVT kandidatundersøkelsen 2013” were released [10]. The participants of the survey were graduate engineers from the Faculty of Engineering Science and Technology. Regarding industrial design graduates, 23 of 45 graduate students from industrial design participated in the survey. 87% of the participants were at the time in permanent employment. 22% were “very satisfied” with their current work, 63% were “satisfied”, 10% were “either or”, 4% were “unsatisfied” and 1% did not know. On the question about if their education were relevant for their current job the answers were; 31% “very relevant”, 56% “relevant”, 8% “either or”. Figure 2 below shows an overview of answers from IPD students.

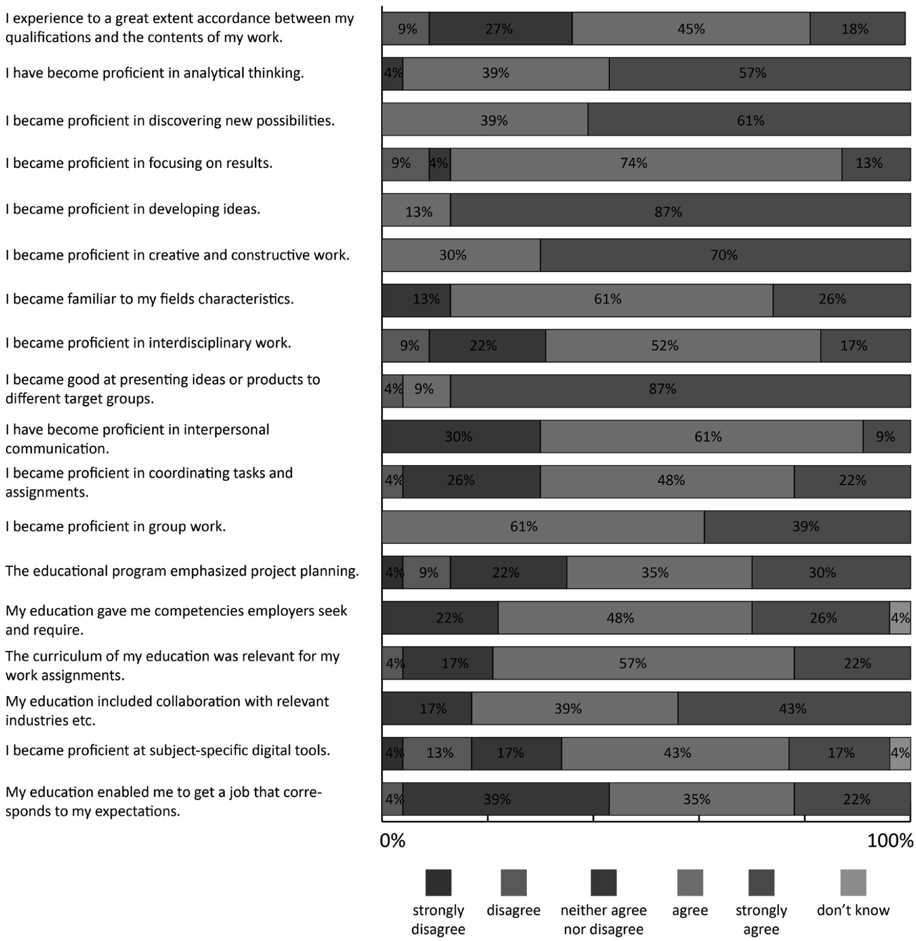

Figure 2. IPD students’ answers in IVT kandidatundersøkelsen 2013

3.2 Interviews with Practising Industrial Designers

All designers from the five in-depth interviews were graduates from IPD at NTNU and employed at the time of the interviews. Their working fields included interaction design, IUX and service design, graphic design and product design. The following questions were asked:

- What do you think about your role as a designer (interaction designer, product designer, etc.).
- What do you assess as important qualifications and knowledge for a designer (interaction designer, product designer, etc.).
- What knowledge, skills and experiences acquired during your education has been useful in you work?

- Critique of the course/study (recommendations for improving industrial design education, what should have more/less focus, what could/should be done different, is something lacking or missing, etc.).

The small set of interviews might usually be considered a limitation. In the present study, however, information was derived from in-depth and detailed descriptions rather than from a large number of interviews [16] and the authors concluded that the interviewee selection was suitable for a description that allowed to show a pattern of common factors. When defining the role of industrial designers regardless of which field of design they work in, although this may not be generalized, one can say that the "superior role" of an industrial designer is to be a person who has an overall understanding of a project and one who keeps an overview. This validates for both the project itself and everything regarding the project. If one attempts to link this up to the core of the industrial design profession to create functionally and aesthetically valuable products and services [4], one can say that both understanding and keeping an overview may be key components in successful execution of the design process. The skills, knowledge and qualifications common for all the designers included understanding, communicational skills, negotiating skills, to be able to systemize and organize, to be able to sell ideas or concepts, and to be able to have an overview over work, projects and information. Important skills knowledge and experiences acquired from education common to the designers were; having learnt design process and design methodology, to have entered the "design mind set", having learnt to manage and complete a project, present and sell an idea or a concept, and collaborate. Almost all the qualifications and skills mentioned above can be found in the five dimensions of characterization of a professional behaviour from section 2 of this article. Suggestions for improving industrial design education by the interviewees included improving the involvement and collaboration with businesses and to use working/practicing designers as mentors and supervisors for projects etc. Further, the building of a proper "toolbox" during the first three years of the study, ample learning of design methodology and practicing the design process and to a greater extent combining of theory and practice was considered relevant. Some of these points of improvement coincide with some of the issues with most dissatisfaction from the surveys in section 3.1.1 and 3.1.2.

4 EVALUATION AND FURTHER DEVELOPMENT

Teaching industrial design students one should provide a set of fundamentals that are helping them to integrate knowledge across disciplines, equipping them with learning skills. Thereby a focus on the "designerly" ways of knowing, thinking and acting, independent from a given application, is what might be most beneficial in terms of improving design education [12-14].

Following findings from the surveys and the in depth interviews together with the interviewees' view, an industrial designer needs competencies and qualifications that relate to both one's professional field and behaviour as well as to the working environment. Competencies and qualifications would include:

- Overall understanding of projects
- to have entered the "design mind set"
- mastering the design process
- knowing design methodology
- to be able to systemize and organize
- to be able to sell ideas or concepts
- to be able to have an overview over work, projects and information
- to be able to manage and complete a project
- to be able to collaborate
- to be able to communicate and negotiate

Recommendations for a better design education include better involvement and collaboration with businesses and industry, and using working/practicing designers as mentors and supervisors for projects to make students accustomed to key aspects of working life. Furthermore, the building of a proper "toolbox" during the first three years of the study to make students become proficient in skills like sketching, 3d-modeling, model making etc. is important. The learning of design methodology and practice to enter the "design mind set" has to be emphasized as well. Finally, it is important to make the goals of the course curriculum more explicit, and the students aware of these goals.

In the future, design schools should add more emphasis on these issues and adjust education towards them. Further research and evaluation for the matters reviewed and discussed in this article is necessary, starting with mapping what can improve the quality in content as well as outcome of industrial design education and comparing studies of design educations across countries. To paraphrase Norman: “Craft skills and carefully honed intuition may have sufficed in the past, when designers primarily contributed form to industrial products, but it no longer suffices with today's complex systems of people, machines, and services. A more systematic approach is required. If designers do not provide the appropriate knowledge, others will do it for them, and it is not apt to be to their liking.” [17]

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HOW DESIGN REASONING PERSPECTIVES PROMOTES PROSPECTIVE ERGONOMICS WITHIN THE TEACHING OF STRATEGIC DESIGN

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ABSTRACT
The current debate in ergonomics centres on the innovation of future products and services. Inherently, this implies a shift from being customer to need oriented, paving the way for a more progressive type of ergonomics, namely “prospective ergonomics”. Prospective ergonomics is a sub-discipline of ergonomics, which shares a common ground with strategic design, through the anticipation of undiscovered needs of stakeholders with respect to imagining new products and services. The aim of this article is twofold. First it discusses the relationship between Prospective Ergonomics and strategic design from an overarching strategic management perspective (see figure 1). Hereby, relationships among strategic management, strategic design and prospective ergonomics will be elaborated using selected business, design and ergonomic frameworks and models. Secondly, it proposes and argues for certain design reasoning perspectives with respect to generic strategy perspectives
Results indicate that strategic design, is mostly aimed at profit making, whereas in prospective ergonomics a balance between performance / productivity on one hand and human well being on the other hand is sought after. Moreover, understanding the dynamics among strategy perspectives, modes of design reasoning, strategic design, and prospective ergonomic modes of thinking allows educators, practitioners and students to be more conscious about their design attitudes and the range of methods and tools they are able to use to target different types of value.

Keywords: Prospective ergonomics, generic strategies, design reasoning modes, strategic design.

1 INTRODUCTION

In the past 25 years, ergonomics did not gain much acceptance by business managers. According to the Administrative Science Quarterly, Perrow argued that the problem of ergonomics is that too few ergonomists work in companies [1]; that they have no control over budgets and people; and that they are seen solely as protectors of workers, rather than creators of products, systems and services.
Presently, the value of ergonomics extends beyond occupational health and safety and related legislation. While maintaining health and safety of consumers and workers, ergonomics has become more valuable in supporting company's business strategies to stay competitive. Given this context, debates in ergonomics centre on the innovation of future products and services. Inherently, this implies a shift from being customer to need oriented, where corrective and preventive ergonomic approaches are paving the way for a more progressive type of ergonomics, namely “prospective ergonomics”. Prospective ergonomics is a sub-discipline of ergonomics, which promote a broad and long-term approach towards anticipating undiscovered needs of stakeholders with respect to imagining new products and services [2]. With respect to methods and tool use, prospective ergonomics rely on numerous data collection methods from a wide variety of disciplines to investigate how human behaviour and needs may determine the development of future products and services [1]. These disciplines include ergonomics, psychology, sociology, management, economics, and engineering.
The aim of this article is twofold. First it discusses the relationship between Prospective Ergonomics and strategic design from an overarching strategic management perspective (see figure 1). Hereby, relationships among strategic management, strategic design and prospective ergonomics will be elaborated using selected business, design and ergonomic frameworks and models. Secondly, it proposes and argues for certain design reasoning perspectives with respect to generic strategy perspectives [4].

This has led to the formulation of the following research questions:
RQ1. What are the theoretical and conceptual differences and similarities between strategic design and prospective ergonomics?
RQ2. How do management strategy perspectives and schools of thought influence strategic design and prospective ergonomics?
RQ3. How do design reasoning and strategy perspectives promote prospective ergonomics within strategic design?

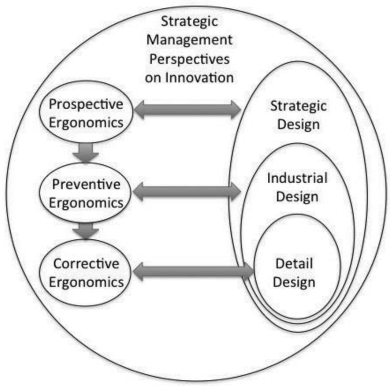

Figure 1. Alignment of ergonomic and design interventions at different levels of comprehension

2 ERGONOMIC INTERVENTIONS ON DIFFERENT STAGES OF THE DESIGN PROCESS

De Montmollin has categorized ergonomic into corrective ergonomics and preventive ergonomics [5]. The former is about correcting existing artefacts, and the latter deals with systems that do not exist yet in reality. Laurig associates "corrective ergonomics" with traditional ergonomics and describes it as developing "corrections through scientific studies" [6]. In this context, "developing corrections" refers to situations where the ergonomist or designer makes user functional improvement to existing products, systems or processes in a reactive manner; in other words "redesigning".
Robert and Brangier have extended the focus of ergonomics by including prospection and by mapping out the differences and similarities among corrective, preventive and prospective ergonomics [7]. Comparisons across the three subsets of interventions, which are interesting to be aligned to a similar comparison within design and strategic design later on, are:

- Nature of work and intervention with respect to temporality and expected outcomes
- Main focus and starting point for human factors activities
- Implications for research and data collection

Nelson et al. proposed to align the product development process with different ergonomic interventions, as shown in figure 2 [8]. Developed around speculative scenario building and use, prospective ergonomics is strongly compared with the Fuzzy-Front-End of Innovation, where future product and / or service proposals are sought after. From this prospective ergonomic perspective, scenarios are intended to assist decision-making at three main stages in the design process [9]: (a) the analysis of problem situations in the start of the process, (b) the generation of design solutions at various levels of complexity, and (c) the evaluation of these design decisions according to UCD criteria. In this context it can be argued that the purpose of scenarios in the early stages of design is not only to provide an accurate vision of future user activity, but also to crystallize designers' current knowledge and assumptions about future activity. Thus, from this point of view, scenarios of future use in prospective ergonomics are not just a material for analysis, but also a product of creative design [10]

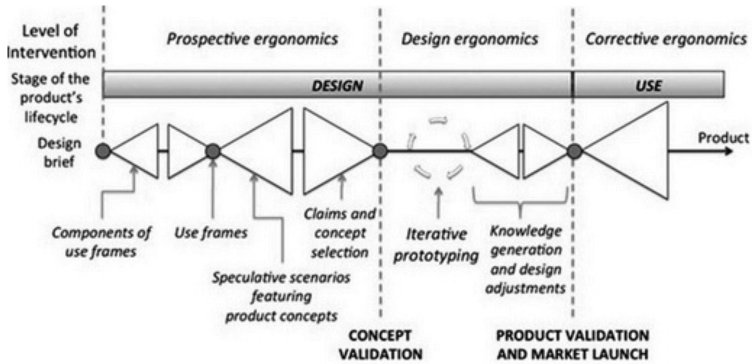

Figure 2. Alignment of the product development process with different ergonomic interventions (Adopted from Nelson, 2013, p. 9 [8])

3 GENERIC STRATEGY PERSPECTIVES

To provide decision makers with fundamentally different ways of thinking about strategy in a wide range of situations, four perspectives on strategy were mapped according to process and outcome (see figure 3) [4]. These perspectives, which are classical, evolutionary, processual, and systemic, have their roots from "Mintzberg´s 10 Schools of Thought about Strategy Formation" [11]. As a precursor to Whittington´s generic strategy perspectives, these schools were compared and positioned on a bipolar spectrum according to planned and emergent strategies [11].

When addressing the "outcomes" axis, "plural" dimension should be interpreted from a more nuanced perspective, considering both the short and the long term, as well as diverse ambitions of all stakeholders within and outside the organization, in contrast to the focused profit-maximizing aims of the organisation leadership. The "processes" axis illustrates a spectrum between deliberate and emergent ways of planning

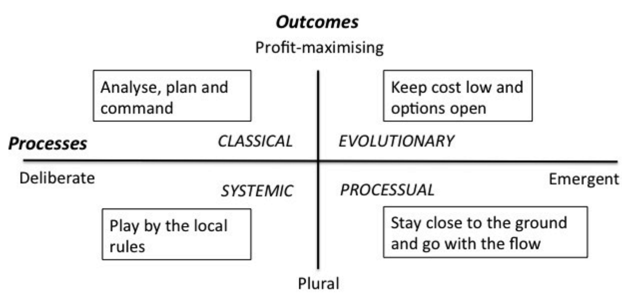

Figure 3. Overview of generic strategy perspectives.

In the classical approach, profit maximising is the highest goal of business and rational planning. This classical theory claims that if Returns-On-Investments (ROI) is not satisfactory in the long run, the deficiency of the business venture should be corrected, or abandoned [12]. Key features of the classical approach are the attachment to rational analysis, the separation between planning and execution, and the commitment to profit maximization [12], [13].

Evolutionary approaches are characterised by an on-going struggle for survival through reactive decision-making. In the search of profit maximization, natural selection will determine who are the best performers and survivors [14].

Processual methods do not aim for profit-maximisation ambitions, but strive to work with what reality offers. Practically, this means that firms are not always united. Instead, individuals with different interests, acting in an environment of confusion and mess, determine the course of action. Through a process of internal bargaining within the organization, members set goals among themselves, which are acceptable to all.

In a systemic approach, the organization is not simply made up of individuals acting purely in economic transactions, but of individuals embedded in a network of densely interwoven social relations that may involve their family, state, professional and educational backgrounds, even their culture, religion, and ethnicity [4].

4 THE IMPLICATIONS OF GENERIC STRATEGIES, WORLDVIEWS AND MODELS OF DESIGN REASONING ON PROSPECTIVE ERGONOMICS

With respect to various perspectives on innovation, philosophical worldviews were introduced as a foundation for the discussion of six models of "Design" reasoning [15], Lie´s extensive literature review has led to a systematic framework (p.68) [15], which illustrates the current dispute between positivistic / deliberate design approaches on one hand and the more plural, reflected and embedded design approaches on the other hand. The alignment of the six design reasoning models, which are "Problem Solving", "Hermeneutic", "Reflective Practice", "Participatory", "Social", and "Normative", with the generic strategy framework [4], shows existing relations and conjectures (see figure 4), justifying the close relationship between design thinking and business strategizing.

Although processes and outcomes are different for strategizing and designing, the understanding of similarities among different generic strategies, worldviews and models of design reasoning will be invaluable for ergonomist, designers and business managers to create better products systems and services. This understanding will lead to an appreciation that strategic perspectives and design reasoning modes are somehow similar in nature in determining innovation attitudes. Furthermore, this alignment will provide a better understanding on how to position ergonomic interventions relative to strategic management, strategic design and industrial design theories. The following sections will elaborate more on these similarities.

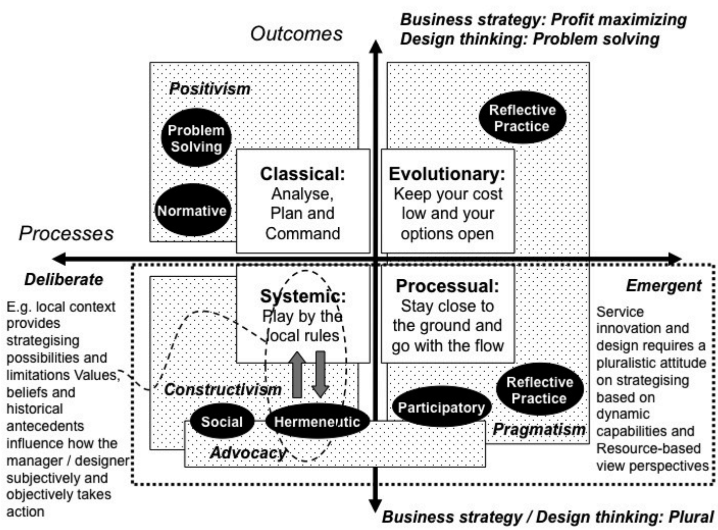

Figure 4. Extension of generic strategies to models of design reasoning based upon philosophical worldviews (adapted from Whittington, 2001, figure 2.1, p.10 [4])

A positivist worldview underpins the classical strategy approach, where profit making is planned and commanded. This is in line with a focused and structured problem-solving approach, where a systematic design process defines the solution space [16]. The normative reasoning model is exemplified by how a strict and concrete program of requirements complements this problem-solving approach. Typically, PMT-matrices [13], and Style / Technology Maps [17], are examples of methods and tools, which supports a planned and structured approach towards innovation and design.

The evolutionary and processual strategic approaches are built upon a pragmatic worldview. Lacking a debate as to whether reality is objective or subjective, the emergent and in some cases opportunistic characteristics of these strategies determine how organizations behave to achieve their profit-making targets or goals. For instance, within corrective ergonomics, an evolutionary business strategy, complemented by a reflective way of designing, would suffice to incrementally improve ergonomic functionality of existing products. Similarly, there are design-reasoning attitudes, which can be aligned with these emergent approaches. The reflective practice addresses design issues from a constructivist, though pragmatic, perspective by engaging in conjectural conversations with the situation [18]. The participatory element, where different stakeholders are actively or passively involved in the design process, bringing along their personal interests, is a real-life and pragmatic phenomenon, which aligns well with an emergent strategy driven by pluralistic objectives, but which may not always lead to profit-maximizing or optimal, economical design solutions. To address such a complex situation, which emphasizes well-being, prospective ergonomics may facilitate the discovery of hidden needs and anticipate future solutions.

The systemic strategy is co-constructed by different stakeholders and individuals in a social context [19]. Although processes are planned and deliberate, multiple objectives exist because of the complexity of multiple views, which are socially, historically, culturally, and contextually embedded in respective communities of practice. From a prospective-ergonomic and strategic design perspective, the designer attempts to anticipate human needs and activities so as to create new artefacts and services that will be useful and provide positive user experience [7]. Reiterating the importance of systemic embeddedness, contexts, values, and functions should be considered here as a key element in getting any collaborative process going, involving different stakeholders.

5 DISCUSSION

When comparing between prospective ergonomics and strategic design, the development of innovative products and services is a common activity in both fields. However, the differences are:

- In strategic design, innovation is mostly aimed at profit making, whereas in prospective ergonomics a balance between performance / productivity on one hand and human well-being on the other hand is sought after.
- Prospective ergonomics aims at developing products, which addresses a product and service, which does not exist yet, and aims at anticipating future needs in certain contexts. The aims in strategic design are more diverse, ranging from product extensions to incremental and radical innovation.

Referring to figures 1, 3 and 4, Whittington´s generic strategy framework forms the basis to position different modes of design reasoning, which either characterises strategic design or prospective ergonomic attitudes towards innovation.

Moreover, understanding the dynamics among strategy perspectives, modes of design reasoning, strategic design, and prospective ergonomic modes of thinking allows designers to be more conscious about their design attitudes as well as clients to be more aware of the broader value of design.

In term of design education and practice the framework as show in figure 4, provides a foundation for design students to be more conscious about the different aims and values of "Design"

It will also have an implication on which methods and tools they should be using according to the outcomes they are aiming at together with the collaborative company and other stakeholders. This implies the need for further research to position methods and tools according to "deliberate versus emergent process" and "performance versus plural outcome" axes in relationship to the different modes of design reasoning. For example, "SWOT", "User testing", "Personas" and "Scenario Development" are typically planned and executed by the designer. "Creative Problem Solving", "TRIZ" and "Storytelling" are tools, which embed a participative involvement, are more suited for addressing pluralistic outcomes for a systemic strategy perspective.

6 CONCLUSION AND FUTURE RESEARCH

Prospective ergonomics has developed from corrective and preventive ergonomics to be more "forward looking in time" by emphasising on context, user-experience and human-centeredness. To identify and develop methods and tools, which are typically suited for prospective ergonomics and strategic design, it is important to first position tools from design, engineering, and the social sciences according to Whittington´s generic strategy framework with respect to modes of design reasoning and worldviews.

In terms of practice, prospective ergonomics created awareness among stakeholders that the anticipation of user needs and imagination of radically new products and services are essential for the survival of organisations and their business eco-systems. Adopting a systemic and contextual perspective, six thematic areas are particularly relevant for further research in prospective ergonomics, addressing global social and economic issues. These areas are: (1) Healthcare and Welfare Design, (2) Inclusive Design, (3) Service Design, (4) Aesthetic and Experience Design, (5) Interaction Design within the context of culture and acculturation, and (6) Transportation Design.

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WHAT ARE DESIGN AND TECHNOLOGY FOR?

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ABSTRACT
In 2011, a report by the Expert Panel for the National Curriculum review in the UK stated, "Despite their importance in balanced educational provision, we are not entirely persuaded of claims that design and technology (D&T), information and communication technology (ICT) and citizenship have sufficient disciplinary coherence to be stated as discrete and separate National Curriculum (NC) 'subjects'". D&T moved from a statutory NC subject to a compulsory one and became part of the 'Basic Curriculum' (with schools free to determine, "appropriate specific content."). It is now 2014 and the ramifications of this reclassification of D&T have impacted upon D&T-linked curriculum in Higher Education. This paper questions the stated perceived lack of coherence in "D&T" as a subject in Secondary Schools, proposes a possible pathway to understanding a framework for D&T curriculum in Schools and suggests how some of the excellent Higher Education D&T practices and outcomes might be maintained and improved upon if such issues were addressed appropriately. At an absolute minimum, Collini proposes, the modern University might be said to possess at least four characteristics: Provide some form of post-secondary education (more than professional training); further some form of advanced scholarship or research not solely dedicated to solving immediate practical problems; these activities are pursued in more than one single discipline; that it enjoys some form of institutional autonomy as far as intellectual activities are concerned [1]. Before defining D&T as a non-subject, consideration must be given to the excellent tradition of D&T in HE.

Keywords: Design and technology, education ecology, education policy, STEM.

1 INTRODUCTION
In 2011, a report by the Expert Panel for the National Curriculum review in the UK stated, "Despite their importance in balanced educational provision, we are not entirely persuaded of claims that design and technology (D&T), information and communication technology (ICT) and citizenship have sufficient disciplinary coherence to be stated as discrete and separate National Curriculum (NC) 'subjects'"[2]. Between 2003-13 there was a recorded 50% drop in the GCSE numbers for Design and Technology in UK Schools [3].

2 LIMITATIONS OF THE REVIEW

2.1 We are not entirely persuaded ICT has sufficient disciplinary coherence
Ruth Kelly, the then Secretary of State for Education, stated in her foreword to the DfES Harnessing Technology strategy report in 2005, "It is our goal to work towards ICT as a universal utility, creating more flexible learning opportunities for everyone."[4].
In 2006, four key objectives were identified, for ICT in Schools to achieve.
These were:
1. to transform learning and teaching, improving outcomes and sharing ideas;
2. to engage 'hard to reach' learners through the provision of special needs support, motivating learning experiences and increased choice;
3. to build an open accessible system with more information and services online, improving personalised support and choice; and,
4. to achieve greater efficiency and effectiveness through the use of online resources and improved systems and procedures.

Government-funded support for ICT really only began in earnest in the mid-1990s. The development of ICT in schools progressed unevenly across and within schools and technologies. Some seem to be content with achieving the government's targets in terms of numbers of computers and connectivity, while others appeared to be highly innovative, attempting to capitalise on the benefits that ICT had promised [5]. These two cited reports do not represent a comprehensive review of ICT in Schools, but they do highlight and typify many of the issues concomitant with the domain. If ICT was regarded, over a period spanning years, primarily as a universal utility, by the people and bodies responsible for strategy and policy, then it can be argued that a review, at the end of that period, was likely to find that there is insufficient disciplinary coherence for it to be stated as a discrete and separate National Curriculum (NC) subject.

2.2 We are not entirely persuaded D&T has sufficient disciplinary coherence

Bruce Archer and Phil Roberts, in a discussion about the course of work in the Royal College of Art's Design Education Unit in 1979, stated, "Design, like science or scholarship, is the product of a distinctive kind of activity and is governed by a distinctive capacity of mind. Designing and the development of technological awareness, as educative activity, consists in relating and drawing attention to purpose, the self, and the means and significance of Man's intervention in his habitat" [6]. Roberts reiterated sixteen years later that, "Design and Technology are not synonymous. Both are nouns, not verbs. The greatest weaknesses in common usage of these terms are philosophical and linguistic. More precise, and qualified, usage - which would involve careful attention to semantics - would have the effect of removing many common confusions" [7]. In 1999, the National Curriculum (first National Curriculum in England to include "citizenship") stated, "Design and technology prepares pupils to participate in tomorrow's rapidly changing technologies. They learn to think and intervene creatively to improve quality of life. The subject calls for pupils to become autonomous and creative problem solvers, as individuals and members of a team. They must look for needs, wants and opportunities and respond to them by developing a range of ideas and making products and systems. They combine practical skills with an understanding of aesthetics, social and environmental issues, function and industrial practices" [8]. This scenario, unlike the ICT story above, would appear to be an appropriate launching point for D&T as a subject, so what are the reasons for the decline in D&T numbers since that time? The Education Act in 2002 extended the National Curriculum to include the foundation stage. This made the six areas of learning in the foundation stage the statutory curriculum for children aged 3–5. Figure 2 shows the structure and illustrates that D&T was not statutory at KS4 (GCSE) where ICT, and indeed citizenship, were. Schools could fulfil the D&T "entitlement" by providing access to courses in the following areas: product design (including textiles technology, resistant materials technology and graphic products) or manufacturing; food technology or hospitality and catering/home economics; systems and control, electronic products, electronics and communication technology, industrial technology or engineering [9]. There, it could be argued, one might find a major contributory factor, to a review panel's claim that there is insufficient disciplinary coherence for D&T to be stated as a discrete and separate National Curriculum (NC) subject. Textiles, resistant materials, graphics, food technology, hospitality, home economics, electronics, communication technology and Engineering all fell under the D&T umbrella, and that broad spectrum certainly does lack coherence as a subject. Indeed there are parallels with the combination of Information and Communication alongside Technology to produce a utility. "Design" and Technology combined in this context look more like a utility than a subject.

	Key stage 1	Key stage 2	Key stage 3	Key stage 4	
Age	5–7	7–11	11–14	14–16	
Year groups	1–2	3–6	7–9	10–11	
English	■	■	■	■	National Curriculum core subjects
Mathematics	■	■	■	■	
Science	■	■	■	■	
Design and technology	■	■	■		National Curriculum non-core foundation subjects
Information and communication technology	■	■	■	■	
History	■	■	■		
Geography	■	■	■		
Modern foreign languages			■		
Art and design	■	■	■		
Music	■	■	■		
Physical education	■	■	■	■	
Citizenship			■	■	

Figure 1. Structure of the National Curriculum (2003)

3 PROGRESS AND ROADMAP

3.1 The Present

Figure 2, taken from the national curriculum in England Framework document (2013), illustrates the structure of the present national curriculum in terms of those subjects that are compulsory:

	Key stage 1	Key stage 2	Key stage 3	Key stage 4
Age **Year groups**	5 – 7 1 – 2	7 – 11 3 – 6	11 – 14 7 – 9	14 – 16 10 – 11
Core subjects				
English	✓	✓	✓	✓
Mathematics	✓	✓	✓	✓
Science	✓	✓	✓	✓
Foundation subjects				
Art and design	✓	✓	✓	
Citizenship			✓	✓
Computing	✓	✓	✓	✓
Design and technology	✓	✓	✓	
Languages[4]		✓	✓	
Geography	✓	✓	✓	
History	✓	✓	✓	
Music	✓	✓	✓	
Physical education	✓	✓	✓	✓

Figure 2. Structure of the National Curriculum (2013)

As can be seen, D&T is not compulsory at Key stage 4, but a development from the 2011 report introduces the concept of four “entitlement areas”: The arts (comprising art and design, music, dance, drama and media arts), design and technology, the humanities (comprising geography and history) and modern foreign language

The statutory requirements in relation to the entitlement areas are: schools must provide access to a minimum of one course in each of the four entitlement areas; schools must provide the opportunity for pupils to take a course in all four areas, should they wish to do so a course that meets the entitlement requirements must give pupils the opportunity to obtain an approved qualification. D&T therefore, as one of the four entitlement areas on its own, must therefore be offered. There is evidence that the DISPARATE DEFINITIONS AND SUBSEQUENT DELIVERY OF D&T over many years, rather than the subject itself, has consistently lacked coherence. Notice also that the subject “Computing” has replaced ICT, partly to define the coding (or writing) requirement as well as utility software packages (referred to as “reading” eg Word, Powerpoint, Excel……). The level of knowledge and skills (or lack of) in such a Computing subject, upon arrival at a University to undertake a D&T undergraduate programme also requires consideration.

On February 12th 2012, the pupils of Chesterton Community College ICT class were invited to road-test the long-awaited Raspberry Pi computer, shortly after the incumbent Education Secretary Michael Gove announced he was tearing up the current ICT curriculum, which he described as "demotivating and dull". Technology journalist Simon Rockman countered this argument: "Today's kids aren't interested (in coding). The world has moved on…what makes their applications work or what is inside the black box is as interesting as the washing machine or vacuum cleaner. [10]. This paper proposes that it has been the underlying attitude to, and prescribed culture driving the DELIVERY OF ICT, rather than the ICT subject itself, that lacked coherence.

Science Technology Engineering and Mathematics (STEM) related subjects have been high on the agenda in the arenas of politics, education and the media generally. Of the four, it might be argued, it is “Technology” that is the least clearly defined and, as a consequence, the least championed, represented and prioritised in any of those arenas. There are one thousand nine hundred and fifty five undergraduate programmes currently offered with Design and/or Technology in the title, with forty nine of them having Design AND Technology in the titles [11]. Many of these have a requirement for a D&T A level or equivalent at entry along with a portfolio assessment at interview. Figure 3 is an extract from the KIS statistics for one such programme, the BSc Product Design and Technology at Loughborough University, in July 2012. UG Design and Technology programmes, as delivered by a number of institutes (Loughborough, Brunel, Northumbria) have delivered hundreds of Industrial/Product Design & Technology graduates over decades who have made significant contributions to society in general, UK plc and the people around them.

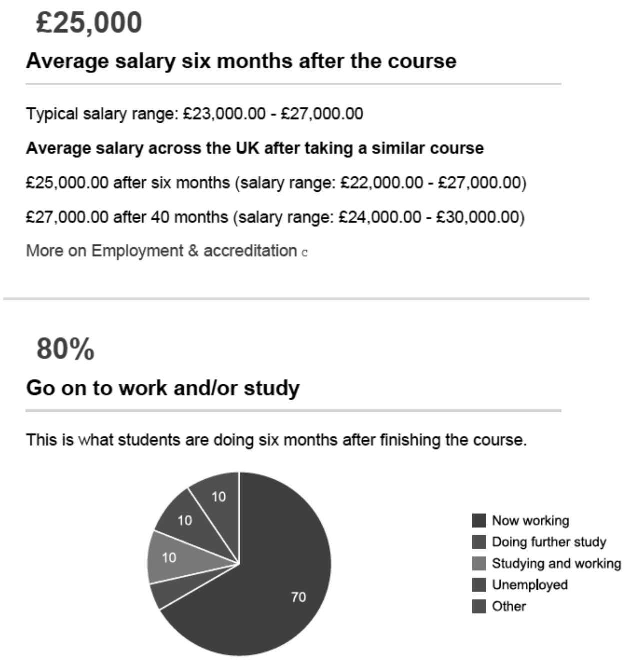

Figure 3. BSc PD&T Graduate Statistics (2012)

4 CONCLUSIONS

D&T, as a subject in Schools, has proven inherently difficult to define with sufficient disciplinary coherence, and this difficulty has been further exacerbated by historical attempts to include such a breadth of seemingly disparate disciplines under the D&T "subject" umbrella. In HE, there are exemplars of D&T programmes with pedigree dating back more than quarter of a century. Indeed the Design and Technology "subject", relating and drawing attention to purpose, the self, and the means and significance of Man's intervention in his habitat, in an HE context offers a seemingly good fit to three of the four minimum characteristics for a University: to provide some form of post-secondary education (more than professional training) ; further some form of advanced scholarship or research not solely dedicated to solving immediate practical problems and that these activities are pursued in more than one single discipline. The fourth, that it enjoys some form of institutional autonomy as far as intellectual activities are concerned, provides the icing on the cake expected for any subject. In summary, education is an ecology and lifelong in nature. Before defining D&T as a non-subject, at key stage 4 in particular, consideration must be given to the excellent tradition of D&T in HE. The cost of grappling with, and arriving at a consensus solution to, the elusive D&T domain will be repaid by the benefits of talented graduates equipped with the means to engage with and lead the enterprising era facing the globe in the short to mid term. There is an ecology here, and those involved at all stages of education must be aware of the potential impact upon other parts of the system, particularly Design education at HE level, in this instance.

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UNCONSCIOUS INTERACTION BETWEEN HUMAN COGNITION AND BEHAVIOUR IN EVERYDAY PRODUCT: A STUDY OF PRODUCT FORM ENTITIES THROUGH FREEHAND SKETCHING USING DESIGN SYNTACTIC ANALYSIS

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ABSTRACT
The development, advancement and critical study of design thinking challenges designers to explore every possible factor in high value innovative design concepts. Designers must expand their thinking parameters and seek values in design activities by analyzing all related factors in human behaviour. Moreover, the need for more communicable and stringent design development strategies of the product's conceptual ideation is increasing. Based on prior studies of human behaviour factors, the theory of unconscious interaction and cognition in human behaviour has shown its value as a guide for designers to create an innovative product design concept during sketching activities. In this paper, selected conceptual sketches generated from an understanding of the theory of unconscious interaction and cognition in human behaviour will be analyzed. This study aims is to analyze form elements and entities implemented by designers using design syntactic analysis as the main methodology. The ultimate goal is to identify which elements visualized (1) the superior gestalt consisting of form entities and form elements of the highest hierarchical (global) level of the product form; (2) the characteristic shapes which indicates the purpose and function of form aesthetics and (3) a signifying curve as a form ingredient which indicates the functional component of product form. The final section will discuss the result and the significance derived from the outcomes of the study. This includes the functional identifications and analysis of form aesthetics, the consistencies and uncertainty elements, and product concept reasoning.

Keywords: Design syntactic analysis, interaction in design, methodology, product design, unconscious human behaviour.

1 INTRODUCTION

In the psychology perspective, unconscious interaction of human cognition and behaviour in everyday life can be explained as an automatic process of being effortless, unconscious and involuntary [1]. Meanwhile, in the design perspective, it can be defined as the subtle and amusing ways that humans react to tangible things and the environment around them [2]. This fits the descriptions of "goodness of fit" and the idea of unselfconscious design as introduced by Alexander [3]. According to Alexander, people unconsciously make a good fit from a misfit as soon as the misfit is recognized. The embodied interaction was triggered by incremental engagements that lead to subjective and possibly unknown improvements in relationships among everyday products, environment and users [3]. The integration of varying and disparate literature regarding this theory has shown extraordinary potential to contribute to product design development (see e.g., [2], [4], [5], [6], [7], and [8]). However, the applicability and the usefulness of understanding the theory may be questioned, specifically in this matter, since the empirical evidence in relation to designers' reflective practice is still considered limited. In this study, the ultimate aim is to understand on how a designer responds to affordance and how the element in design ideation is generated based on affordance, how it is determined. Hence, this study requires an extensive observation methodology as means to extending the knowledge about designers' design activity.

1.1 The attributes of unconscious in everyday behaviour

Norman [9] concedes that there are three levels of emotion interactivity, namely: (1) visceral; (2) behavioural; and (3) reflective. In this study, the attributes of unconscious in everyday behaviour were derived and adapted from Norman's idea of behavioural interactivity. Through a cautious and repeated process of analysis, design cases and psychology literatures regarding unconscious behaviours, Sohn, Nam, and Lee [6] determined four attributes of unconscious in everyday human behaviour, namely: (1) adapting; (2) reacting; (3) signalling; and (4) conform to others (see Figure 1).

The existence of 'initial intention', 'individual and 'social' are the key factors to distinguish between these four attributes. Some automatic interactivities do not require any willful initiation and operate quite independently of conscious control and many of the behavioural interaction we do every day are things of which we are perfectly aware [10]. However, we no longer need to think about the act after we have consciously launched it because we have done the act so often. These behaviour interactions are often acquired skills, actions that become automatic only after significant repetition. Therefore, the attributes can be instigated by stimuli of which we are not yet conscious, or by stimuli of which we were recently conscious but are no longer.

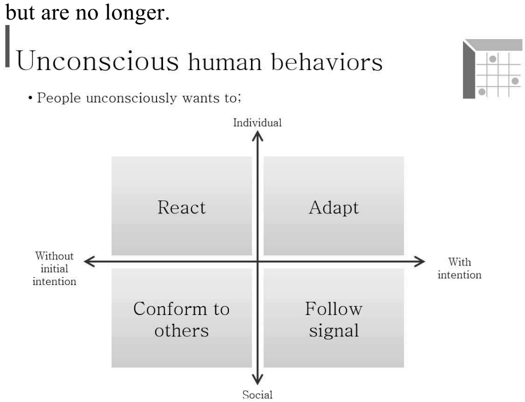


Figure 1. Four attributes of the unconscious in everyday human behaviour, adapted from Sohn, Nam and Lee [6]

1.2 Design syntactic analysis

Design syntactic analysis is a methodology to analyze form [11] entity relations that reveals a consistent treatment of a visual composition, functionality and design format (see Figure 2). There are three form entity levels in describing an evidence of aesthetic organ structure, communicative functions and characteristics of form elements. Referring to Warell [12], those three levels can be identified through: (1) The superior gestalt level: consisting of form entities and form elements of the highest hierarchical (global) level of the product form (outer shape); (2) The intermediate level (form features): consisting of significant characterized shapes and form elements (features) of product form (inner shape); and (3) The lower level (product component): a signifying curve (form ingredient) is distributed across the product form. Understanding these from entity levels is claimed contribute to identifying design syntactic (structure establishment) reasoning implemented in designers' conceptual sketches.

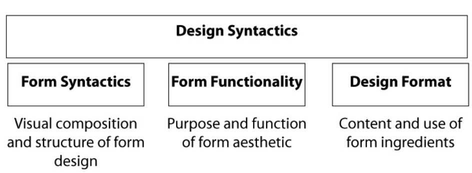


Figure 2. The theoretical framework of Design Syntactic, adapted from Warell [12]

2 RESEARCH OBJECTIVE

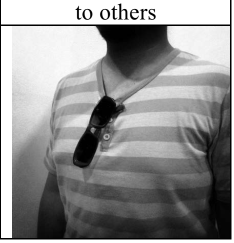
The study concerning theory of unconscious interaction of human cognition and behaviour in everyday product has been explored by integrating a variety of disparate literature. However, there

was no study found which tries to understand the designers' sketching process based on affordance using the theoretical basis of reflective practice and design syntactic analysis. Moreover, numerous studies on the designers' sketching process has contributed to the formulation of the objective of this research: to use design syntactic analysis to understand designers' sketching process in relation to the theory of unconscious interaction of human cognition and behaviour in everyday product.
The overall research question guided the investigation regarding how designers' conceptual ideation devoted to the theory can be understood. Based on findings reported from previous studies, there were three sub questions developed as follows:
RQ1. An analysis of form entities reveals a consistent treatment of a design format and an evident aesthetic organ structure. Thus, which part in designers' ideation sketches were generated in relation to the theory has a consistent treatment of a design format?
RQ2. It is argued that uncertainty is the primary factor triggering change in sketching structure and drives invention in design. Thus, are there any uncertainty elements of form entities existing in designers' sketches in relation to the theory?
RQ3. Form entities in design carry aesthetically determined functionality. Thus, what are the functionality elements embedded in designers' ideation devoted by their reflections on the theory of unconscious interaction of human cognition and behaviour in everyday product?

3 METHODOLOGY

In this research, we explore how designers generate conceptual sketches based on their understanding, analysis and reflection on the theory of unconscious interaction and cognition in human behaviour. We also study the characteristics of these conceptual sketches in order to determine and describe the ingredients of the visual form composition such as the shapes and their arrangement, in an objective manner. Therefore, we explore the designers' sketching activity by understanding their reflective practice [13] and critically analyze them using design syntactic analysis [12]. The investigation was based on two studies:

Table 1. The polar images

Image A: adapting	Image B: signalling	Image C: reacting	Image D: conforming to others
			

In study 1, a total of 30 practicing product designers, product design students, and educators were selected to participate in Verbal Protocol Analysis (VPA). During the VPA, they were given four polar images (coloured) that depict the subtle and creative ways in which people interact with a product. The polar images were categorized into Sohn's four attributes of unconscious in everyday human behaviour [6] as in Table 1. They were asked to generate conceptual ideation sketches based on their understanding, analysis and reflection on each polar image. Hence, each designer participated in four episodes of VPA in connection with these four attributes.
In study 2, there were a total of 10 respondents; master's degree level design students were asked to analyze four conceptual sketches which were generated from study 1. As a reference, four polar images (grayscale) the same as Table 1 were given as well. The respondents were asked to identify design syntactic (structure establishment) reasoning implemented using a coloured pen on each sketch (printed on A3 paper sheets) through: (1) the superior form level (outer shape); (2) the intermediate form level (form features); and (3) the lower form level (product component) [12]. Finally, the material produced in study 2 was critically analyzed by the authors with respect to: (1) the consistencies of structure establishment analysis by respondents; (2) the uncertainties elements of structure establishment existed in designers' sketches compared to the polar base images; and (3) the functional identifications and analysis of form aesthetics in designers' sketches.

4 FINDINGS

At the end of Study 1, four conceptual sketches from each episode were generated by 30 designers which make a total of 120 conceptual sketches generated during study 1. Out of 120 sketches, four conceptual sketches were selected by the authors based on a heuristic quality review. Results from Study 2 are illustrated in Figures 3. In Figure 3, the frequency of consistencies elements in three level of form entity as indicated by respondents are illustrated in the set of four sketches. Moreover, the uncertainty elements of three level of form entity, and direct functional identifications were also illustrated as well.

Based on the result, the author found that the ability of the designer to realize intent made performance results vary considerably between designers and between the assignments given. According to VPA data, the result shows that designers are able to understand the context of the main theoretical basis. In general, they are capable of extracting their perceptions in relation to Sohn's attributes [6]. Moreover, we found that designers are proficient enough to construct a critical analysis to determine the 'misfit' in given polar images and reflect on how the embodied interaction portrayed could contribute as valuable factors in enhancing products values.

Reflective practice and thinking, as described by Schön [14] will lead to new interpretations and present opportunities for new solutions in the process of sketching as performed by the designer. As reflected in this study, designers produced a conceptual ideation that solved the 'misfit' as follows: (1) mobile charger with automatic roller in its body in order to solve the messy cable management; (2) a parking meter with a digital screen indicator for signalling purpose when the product is malfunctioning; (3) a pen with chewable cap, purposely to provide comfort of biting reaction; and (4) sunglasses with hanging cable and built in mp3 speaker (see Figure 3).

5 DISCUSSION

Our discussion of this research focuses on the characteristics of designers' conceptual sketches in relation to the theory of unconscious interaction of human cognition and behaviour in everyday products. The sketching process has been investigated based on the proposed research questions with respect to three characteristics: (1) consistency: describing the establishment and reliability of structure establishment reasoning as indicated by respondents; (2) uncertainty: denoting the triggering factor of change in design which drives the product invention; and (3) functionality: describing product functionality embedded in designers' ideation devoted by their reflections on the theory and polar images. Figure 3 exhibits the analysis of design syntactic in designers' ideation sketches, which was generated in relation to the theory of unconscious interaction of human cognition and behaviour in everyday products. The analysis underscores which elements represent the structural establishment of form entities in each of the conceptual sketches.

In order to address the first research question, the structure establishment of form entities were identified on the notion of consistency as indicated by respondents (similarities elements existed between the sets of design syntactic analysis indicated by respondents). In Figure 3, the frequency of consistencies element indicate the consistent treatment of a design format implemented in each level of form entities. As analyzed and indicated by respondents, the elements of structure establishment in each level of form entities were determined by a high level of consistency (most indicated elements between sets of analysis by respondents).

In response to second research question, Figure 3 illustrates the result of uncertainty elements of form entities existed in the conceptual sketches. In this research, the uncertainty elements were identified on the notion of which elements were partially transformed or changed throughout the stages of the sketching process, compared to the polar images. The term uncertainty is used to refer to a change in design through recognition and promoting reasoning about the depicted ideation. By comparing each level of form entities with the polar images, the author identified the changes which led to aesthetic value and innovation. These changes are the triggering factors in design that drives product invention.

Finally, with respect to the third research question, the result of form functionality analysis is indicated in Figure 3. The main purpose of analyzing the functionality of the constituent form elements is to identify the underlying design intent. According to Warell [12], the analysis covers all functional aspects of the product under study, including internal functions (i.e. structural, transforming, and additional functions) and interactive functions (ergonomic, syntactic, and semantic functions). In this research, the approach was based on direct functional identification supported by triangulation analysis of VPA data. During functional identification, the sketches under study is scrutinized with the objective of identifying functions which belong to different classes by direct observation.

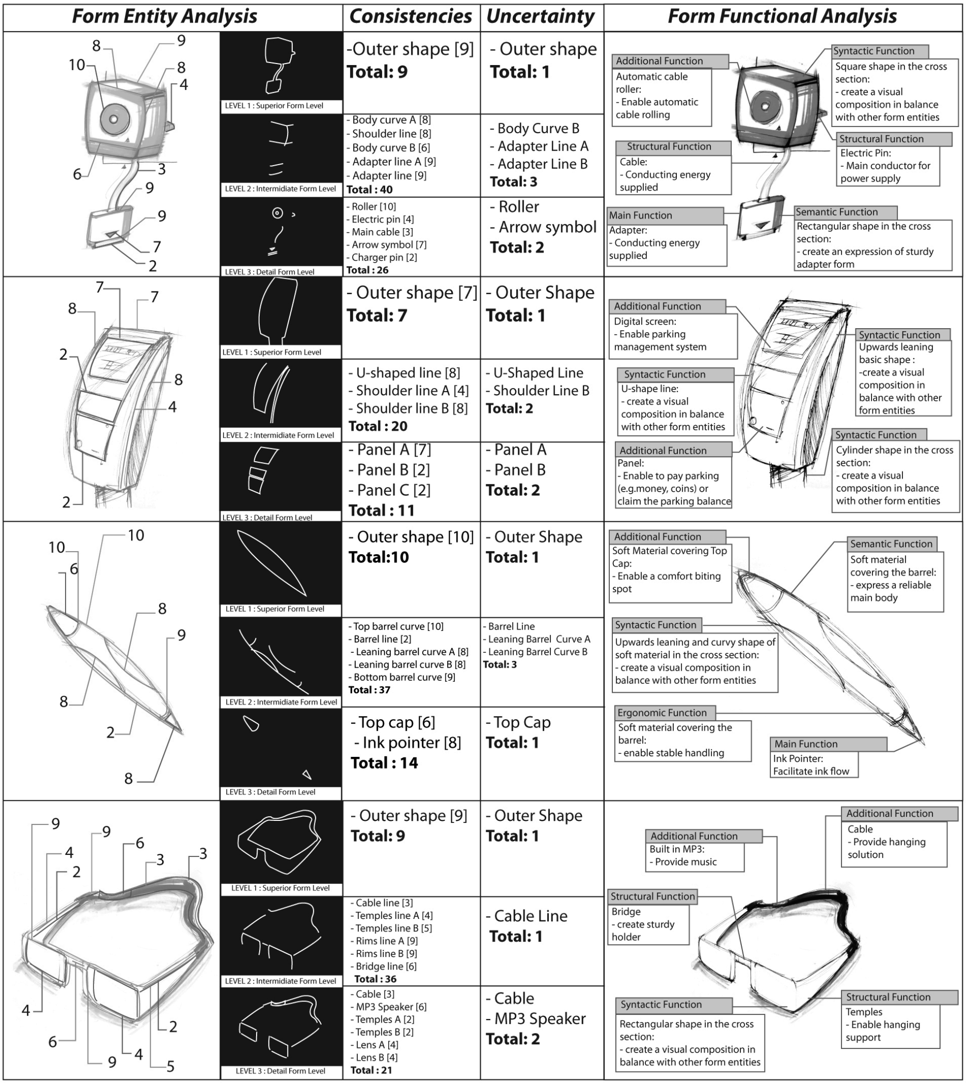


Figure 3. The result of Study 2

6 CONCLUSION

6.1 Advantages of understanding the theory of unconscious interaction of human cognition and behaviour in everyday product

This study expands the design continuum of artefacts used in our everyday life, defined as everyday products in relation with the theory of unconscious interaction of human cognition and behaviour. In this paper, our hope is to provide a better understanding about the possibilities of looking at the realms of unconsciousness and embodied human interaction for product innovation. In finding a fit between human values, designers should start to understand critically and looking at every tiny factor existing in human interaction and behaviour, including the realms of unconscious. This does not involve the mere replacement of a term; rather, the role of unconscious interaction of human cognition and behaviour in everyday products must be considered broadly. Through the content analysis of literature and scientific evidence from empirical study, we argue that the theory of unconscious interaction of human cognition and behaviour in everyday products provides significant value as a new thinking parameter in design. A collection of cases depicted an embodied interaction, the subtle and creative ways in which people interact with the product have inspired designers to consider actual contexts and people's responses to those contexts.

6.2 Advantages of Design Syntactic Analysis as a Methodology in Design Education

Based on the empirical evidence, using design syntactic as an analysis methodology provides ways of approaching aspects of structure establishment and form entities, innovation elements in design and functional identification of the designed product in relation to the theory. Since the form design development is a crucial part in the designers' design process, the higher institution or design school should consider implementing design syntactic analysis methodology as part of a special curriculum in the education. The curriculum should emphasize giving understanding about design syntactic analysis as a systematic approach that synthesizes the form elements in order to better understand the visual composition and structure of form design, functionality of form aesthetics and format of form ingredients. By doing that, students' reasoning ability on form structure establishment in conceptual ideation may be increased.

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DESIGN OF PEDAGOGIC TOOLS FOR TEACHING MATERIALS IN PRODUCT DESIGN ENGINEERING

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ABSTRACT
The education in materials constitutes a vital part of the education of an engineer, since its comprehension determines the design and construction of products with appropriate materials that satisfy the current and future needs of the 21st century society [1]. In the Product Design Engineering degree, teaching and learning the attributes and applications of materials shouldn't be limited to lectures. This paper shows how through the design of pedagogic tools it is possible to go from a knowledge-transfer method to a student-centred method where motivation, teaching and learning strategies and problem-based learning, support meaningful learning [2] through the implementation of these tools in the classroom.

Keywords: Learning strategies, pedagogic tools, competences, materials, design.

1 INTRODUCTION
Nowadays, teaching and learning in materials constitutes a challenge: integrating materials science with the needs related to engineering and design demands teaching methods that allow the professional to assume a more global vision in order to meet the needs of society [1]. Mike Ashby has done a significant contribution by developing books with different approaches to the ones found in traditional books of materials science, and are accompanied by the *CES Edupack* [3] software to manage information. Spaces like *Matter FAD* [4], *Material Connexion* [5] and the design fairs have changed the way to access the information on materials and the promotion generated by these organizations helps designers to be updated and face the changes in the material world. However, understanding the basic information about the attributes of materials, such as their magnitudes, concepts and meanings in a technical specifications sheet, demands from the student experience and learning beyond having read engineering books or listened to a lecture. The contribution to teaching and learning in materials made by Universidad EAFIT lies in the development of pedagogic tools that aim at increasing students' motivation, promoting meaningful learning of the contents of the subject, and supporting the role of the teacher as a coach and not as the centre of attention. These remove -Power point- and teachers' lecturing as the only teaching strategies, and replace them with new ones that can be more useful to learning and promote the competence in the PDE profile.

2 METHODOLOGY
The design of the pedagogic tools was part of a sabbatical semester 2014-02. For their development the following stages were followed:

Phase 1: the first step was to diagnose education in materials globally and locally. Then, the pedagogic model of Universidad EAFIT, which promulgates a student-centred model, was reviewed, and then concepts related to pedagogic tools were examined, articulating them around the aforementioned model. Figure 1 summarizes these steps. It was taken into account that the previous model of the subject had the teacher and lectures as the centre; in the new model, the student is the centre of the process and the teacher acts as a coach. The teacher designs the learning environment in the classroom using several resources, so that through motivation, encouragement and development of problems, meaningful learning of basic topics of materials science takes place.

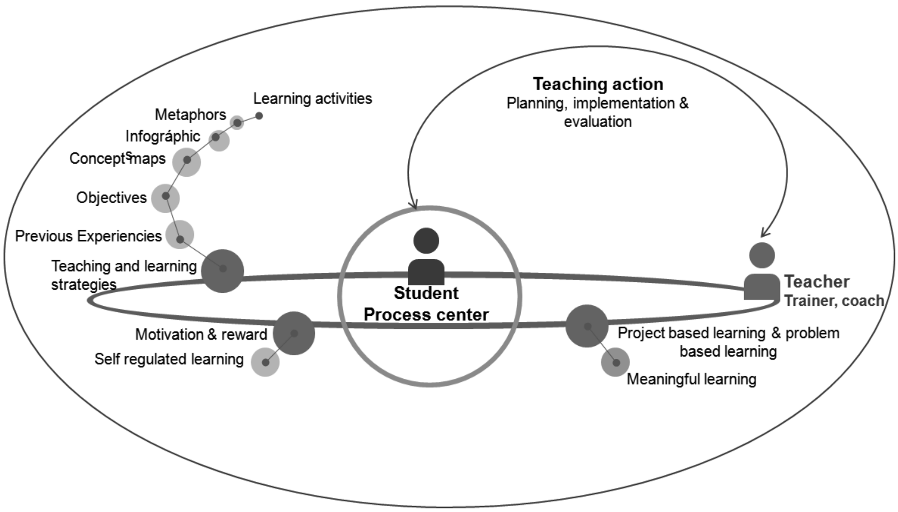

Figure 1. Pedagogic model to be developed for the subject "Materials in design"

Phase 2: for the development of the previous model, the starting point was an input-output scheme as the basic outline to design the course, taking into account the previous knowledge, the competences to achieve in the student and the field of development which enables the student to go from point A to point B. The field of development is the place where all the strategies for the course, which constitute the core of the project, will emerge. See Figure 2.

The *previous experiences* [6] comprise the experimentation with materials in other subjects where design projects have been developed, the representation of different materials and textures through drawings, and engineering knowledge from subjects such as physics or chemistry. Regarding the competences expected there is a consideration of competences from knowledge, know-how and attitudes.

In relation to *what students must know,* several aspects are taken into account: recognize the different families of materials understand the technical and sensory attributes, comprehend why some materials are used in certain products, and use materials to solve problems in the design process. To answer the question of *what type of know-how students need,* skills such as identifying possible materials for their projects according to the restrictions of a brief, knowing where to find and how to interpret information about materials to use it appropriately when designing. Finally, *the attitudes students should have* are motivation, curiosity and a permanent disposition to learn about materials, decision-making and problem-solving abilities, and creativity to solver situations innovatively. [7]

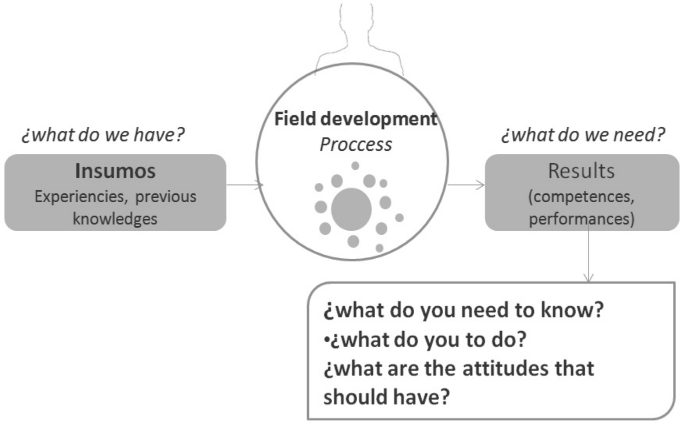

Figure 2. Field of development to design the course "Materials in design"

Phase 3: from this plan, the product design process was adopted as a model for the initial process to design the subject *Materials in design* in six stages: problem definition, generation of the concept, embodiment, detail design, production and implementation. After each stage, came the development of four transversal models based on the MISA method, -engineering learning systems method- which was adopted for this project.

- Knowledge model: what competences must the model develop and who is it aimed to?
- Model based on pedagogic tools: how will the competences be developed and what is the strategy that follows?
- Resources model: what materials are needed for the task?
- Course management model: what are the roles of the teacher and the student in this model?

This process is presented in Figure 3.

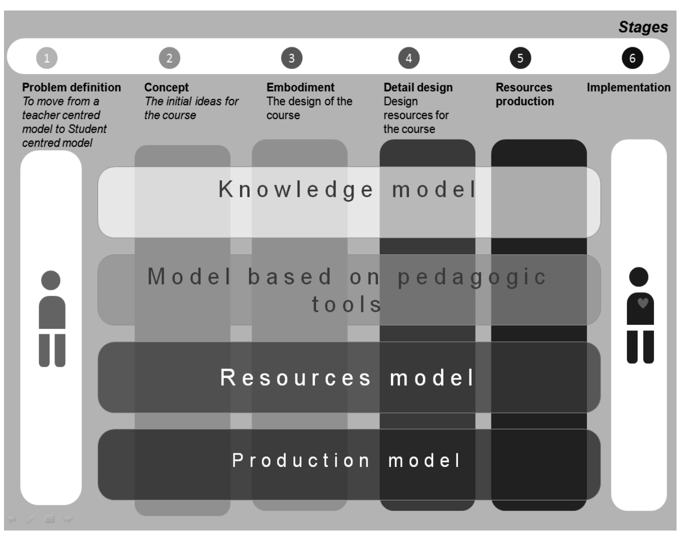

Figure 3. Teaching in materials model for Materials in Design in PDE

With the development of this model, it was possible to clarify what pedagogic tools were necessary for the six units that comprise the subject, namely: the role of materials in the discipline of design, attributes of materials, metals, ceramic and glass, polymers and compound materials.
Phase 4: pedagogic tools for each unit of the subject were created according to the competences expected from students. In each unit, the tools seek that the teacher acts as a coach that accompanies the student who, in turn, tries to regulate his own learning process. These tools are described in Figure 4.

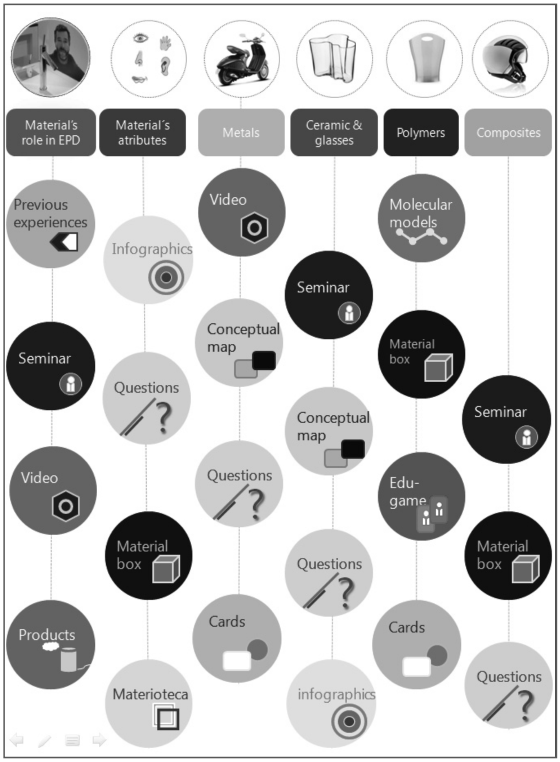

Figure 4. Pedagogic tools for the subject Materials in design

For example, unit 2, *Material's Attributes*, a magazine with infographics called *"Material's Attributes"* is used. This resource connects the properties of materials with comics' superheroes. See Figure 5. Each page describes an attribute, why it is important to understand it, how it is measured and units employed, and finally, the reasons why materials can fail in use conditions in relation to the attribute detailed. Students read the magazine in the classroom, discuss, and, at their own pace, make questions about information that needs clarification; the teacher guides the process and strengthens concepts with other pedagogic tools. In this case, for example, he uses a materials box with samples and objects that help to explain phenomena of the materials, for instance: using a rubber band to explain the concepts of strength and deformation, or using a *Nitinol* wire to explain thermal expansion. At the end, comes the *Materioteca* –a library of materials in partnership with *Material Connexion*- to analyze the sensory attributes of materials and students complete an assessment activity which involves choosing a product, comparing its attributes, understanding why is made of that material and analyzing values and magnitudes.

In the case of unit 3, the project created four different videos supported in motion graphics with the objective of introducing the topic of metals and accompanied by concept maps and index cards that explain the relationship between the microstructure of materials, their attributes and applications.
For unit 4, infographics are used as an assessment activity and concept maps as pedagogic tools to introduce the topic of ceramic and glass. The topic Polymers is supported in videos, molecular models, the material box and an educational game to explain the divisions between the main families of polymers called "*Polimeria*". Finally, the unit on compound materials is organized with an open seminar where two teachers share their experience and knowledge in front of the class and encourage students to make questions about the topic.

Figure 5. Using infographics as a pedagogic tool in the classroom

Phase 5: for each unit of the course, a work guide for the teacher was designed where he can find the competences to be developed, the time for the activities, the setting (outdoors or indoors), a description of the tools, how to use them and what is their contribution to learning. In addition, there are references for the learning and evaluation activities, presentations and bibliography. The design of these guides is shown in Figure 6.

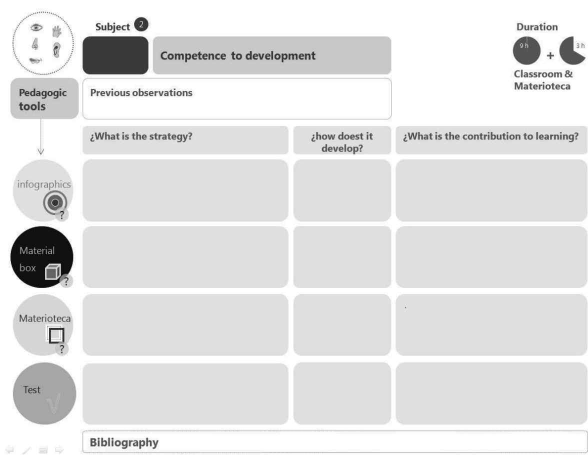

Figure 6. Work guide for teachers of the subject "Materials in design"

3 RESULTS

Currently, the course *Materials in design* of the fourth semester is using the pedagogic tools (2015-01). The project is now in a validation stage, which will be carried out with an academic peer who is teaching the same content with a traditional pedagogic model. Once the semester ends the results will be compared quantitatively and qualitatively to verify the effectiveness of the new learning model described in this project. As to this day, some positive effects in the classroom have been observed:

- Higher motivation in students: there is a perception of higher understanding of the concepts studied because of the implementation of the pedagogic tools, or what Woolfolk defines as “intellectual achievements”.
- An increase in students’ participation: the teacher guides the activities and the students read, ask, analyze and understand information –previously only the teacher talked.
- A more productive use of time and resources: by removing power point presentations, lecturing and dictation up to a 90%, time is now employed in making questions, comparisons and analyzing new materials that supports the explanations.
- Higher interest in the topics: since the class is designed with several learning strategies, there is a dynamic that prevents lack of focus, boredom and monotony.
- Usage of metaphors, infographics and concept maps allows higher retention: similarities and analogies help learning, and as students themselves say: “we can retain more easily with examples”.

This change has allowed breaking paradigms and understanding that there are other ways for engineering education that can replace the traditional ones, and can support higher learning in the classroom. In addition, it adjusts with the new pedagogic models that some universities want to employ, seeking that their students use knowledge more creatively to solve problems in practice.

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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EXPLORING LASTING USER-PRODUCT RELATIONSHIPS, MEANING AND MATERIALITY

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ABSTRACT
Investigating lasting user-product relationships means looking essentially at post-purchase user behaviour. This subject highlights meaning and symbolism in objects and questions the role of materiality. This is a study area with particular relevance to design for sustainability, going far beyond strategies for longer product ownership resulting in less product production. Studying lasting user-product relationships can generate understanding about our relations to physical artefacts and what might constitute sustainably appropriate physical product related behaviour.
This paper reviews recent research literature informing lasting user-product relationships and discusses the theoretical frameworks currently proposed for the subject. We detail a selection of key themes that emerge, and may constitute a possible structure for addressing this subject in design education and practice. These frameworks and themes were part of a number of teaching modules of different lengths addressing the subject of lasting user-product relationships. We finish with a brief presentation and discussion of these teaching case studies, highlighting some of the opportunities this subject affords.

Keywords: Lasting user-product relationships, sustainable behaviour, attachment, materiality.

1 INTRODUCTION

User-object interactions are at the centre of design education and practice, with the objects treated by designers becoming progressively more intangible. In order to determine which physical experiences can be replaced by virtual experiences, we need better understanding of the role of physical artefacts for the people who interact with them. Research into lasting user-product relationships can be an effective way of addressing this question.
Existing research proposes that designers can contribute to the environment through making long-lasting products [1]. We can try to conceive emotionally durable designs [2] embedding less transient, enduring values within products that may be sustained through the passing of time. Schifferstein et al [3] suggest that when a person becomes attached to an object he or she is more likely to handle it with care, repair it when it breaks down and postpone its replacement as long as possible.
Design for product longevity [2] can be based on the stages of product ownership [4]; pre-acquisition, early ownership, mature ownership, pre-disposal and post disposal. A potential difficulty for stimulating product attachment through product design is that consumers do not actively search for it at purchase [5]. Rather than solely focusing on the early stages of ownership, and pre-acquisition, designers need to enhance their understanding of user behaviour in relation to physical products in daily life contexts. Attachment theory shows that after purchase there is a process of progressive meaning-making in product relationships, but it is interesting to also address the role of physical products in daily-life meaning making.
For future designers, not only conceiving, creating and making but understanding is key. Looking at existing product relationships may give useable insights for application in contexts such as up-cycling, service design scenarios and shared-use products. This subject can help designers develop and refine research tools relevant to longer-term enquiry and encourage a focus on longer time frames.

2 USER-PRODUCT RELATIONSHIP FRAMEWORKS

The question of lasting relationships with material products is covered in two inter-related research areas; attachment and emotional durability. Attachment theory is closely linked to consumer research,

whereas the question of lasting or durable product relations, perhaps first addressed in anthropology, is now part of experience design and design for empathy.
The focus of this paper is on lasting product relationships but certain frameworks that do not directly address the question of longevity may still be useful for structuring the subject.

2.1 Attachment

Product attachment is defined as the strength of the emotional bond a consumer experiences with a specific product [5]. Attachment possessions are ordinary objects that have special meaning formed through experiences involving the object [6]. Kleine and Baker's definition of an attachment relationship defines nine constitutive characteristics; a specific material object, one that is psychologically appropriated, singularised, is a self-extension, contains some personal history, some strength, is emotionally complex, is dynamic and is multi-facetted. Key characteristics mentioned are self-definition and self-continuity/change. Empirical product-attachment research [5,3] shows support for the importance of the private and public self, represented by memories, but also for the diffuse self [3] represented by product-related enjoyment and pleasure. The self is divided into four facettes; diffuse self, private self, public self and collective self.
The importance of self-related meanings is central to product attachment theory. This in turn is based on the premise that we regard certain possessions as parts of our selves [7] and that possessions are an important component of sense of self. Russell Belk's key work on the role of the extended self [7] looks at frameworks such as Sartre's Having, Doing and Being. People seek, express, confirm and ascertain a sense of *being* through what they *hav*e, and *doing* is the transitional phase between the two. Belk mentions that Marx considers doing and working the most central to self-worth, and like Fromm, rejects the having mode as being unrewarding.
Another possible framework is that of Arendt [8]; the two different ways of cultivating a sense of self being through action or contemplation. User-product research findings [8] identify noticeable gender and generational differences in preferences for action and contemplation objects.

2.2 Needs and Pleasure

The diffuse self, or pleasure area mentioned above is hard to define. Linked to innate body related reactions, the diffuse self is seen [3] as striving for hedonic satisfaction. In product relations this includes sensory pleasures experienced during usage and aesthetic pleasures derived from appearance and familiarity.
In order to give structure to the notions of enjoyment and pleasure the four pleasures framework [9] can be useful. Starting from Maslow's hierarchy of needs, Jordan [9] creates a consumer needs hierarchy (functionality, usability, pleasure) where functionality is the minimum and pleasure is the emotional benefit people will seek beyond (but often including) enjoyment in usability. This framework aims to help categorize the different types of pleasure people may seek or experience [9]. The four distinct types of pleasure are physical, social, psychological and ideological. Physio-pleasure relates to bodily experiences and sensory organs, touch, taste and smell. Socio-pleasure is linked to relationships with others. Psycho-pleasure relates to cognitive and emotional reactions experiencing a product, ease and enjoyment in use. Ideo-pleasure relates to values, tastes and personal aspirations.
Pleasures are to be understood as being either need pleasures; those that relieve discontentment, and appreciation pleasures; positive or additional to a state that may already be contentment. Jordan suggests that a pleasure-based approach to design must be based on understanding individuals. The four part framework facilitates clustering and organising human factor characteristics which in the pleasure area are expected to be diverse and personal.

2.3 Emotions and Processing

The four pleasures framework is presented as a classifying tool for designing pleasurable products, without a particular emphasis on hierarchy. The approach taken by Donald Norman [10] refers to emotions rather than pleasures and establishes a model describing three different levels of brain processing controlling everyday behaviour. The three levels are a) the visceral level, also known as the sensory/aesthetic or form-related response in other literature [11], b) the behavioural level, also sometimes referred to as response to function and the c) reflective level or meaning related or personal/symbolic response. In Norman's model the three levels interact with one another and modulate each other and have the capacity to generate positive or negative affect and emotions. The

three levels are placed vertically, so as to explain "top-down" behaviour, coming from the highest reflective level, and "bottom-up" activation, driven by perception and feeling. Although Norman's model is very close to models of cognitive response to product visual appearance [11], it does aim to describe what happens in everyday product interactions and not only visual interactions.
Norman links the reflective level to long-term product relations, but not the visceral and behavioural levels, focused on feelings and experiences using products in the immediate time-frame and mainly sub-conscious. For lasting user-product relationships a different model may be needed to understand how habit and automatisms could modify the importance of reflective level processing. In neurological research close to Norman's model, more emphasis is placed on sensory and body related processes. [12] This framework is nevertheless useful for expressing the role of emotions and the continuing mutual influencing and updating of information processing [12] from both high level cognitive activity and body/sensory related activity.

2.4 Durable Relations

In research more directly linked to lasting relations, Stuart Walker [13] looks at enduring artefacts. Rather than individual user-product experiences, the start point is artefact categories existing in one form or another in human societies for millenia. The three broad categories into which product characteristics are classified are 1) functional, 2) social/positional and 3) inspirational/spiritual. The categories are discussed with regard to sustainability and category combinations are presented as being more or less problematic. The functional and social qualities combination is seen as the most short-lived value, with the social category in Walker's model closely linked to social status. Complex object types combining all three categories are seen as containing fundamental lessons for design of sustainable products. Exploring the example of prayer beads as a complex, enduring object, Walker concludes that an artefact relationship involving physical object qualities, physical activity, tactility, visual understanding, aesthetic experience, meaning and inner growth has the potential to become a precious personal possession. Walker puts emphasis on products having profound meaning potential, but also emphasizes the need for combined physical, tactile and meaning-making qualities.
Support for a multi-facetted experience can also be found in empirical research into lasting user-product relations by Odom, Pierce, Stolterman & Blevis [14]. Their work uses a framework of three perspectives that affect durability; function, symbolism and material qualities, from Peter Paul Verbeek. Analysing data from detailed personal inventories, Odom et al suggest that mutually reinforcing interrelations among function, symbolism and material qualities contribute to a high strength of attachment to an object. In line with theories proposed by Verbeek, material qualities are seen as particularly important and are present in the four relationship clusters proposed by the authors. These clusters are; 1) engagement; objects that promote physical engagement during use, materially engaging interactions; 2) histories; the extent to which materials of an object preserve personal histories and memories, both through signs of use or through their sheer persistence over time; 3) augmentation; objects that gain symbolic, creative and personal value through modifications, reuse and alterations, 4) perceived durability; the extent to which an objects` owner regards an object as long-lasting in function and/or longevity.
Odom et al highlight the complex nature of people’s relationships to objects, and place emphasis on the capacity of material qualities for forming more meaningful and useful relationships over time. Time itself, as a contribution to the relationship, is also present in three of the four clusters proposed.

3 KEY THEMES

This brief overview of existing research can provide a simplified framework with different levels of processing/reception from a cognitive/ideological level through to a visceral/instinctive level. We also have support for the idea that lasting user-product relationships are likely to be multi-facetted, and that all levels of the framework should be activated for lasting relationships. We probably need to consider the importance of different time scales, and also the fact that lasting user-product relationships are highly individual experiences.
In addition to this simplified framework, there are four themes or families emerging from existing research that deserve particular attention when considering lasting material product relations. These four broad families also constitute a way of conceptualizing what may exist in lasting user-product relationships, and can be a form of check-list for a multi-facetted design approach. The four themes developed below are self/meaning, function, material qualities/materiality and time.

3.1 Self and Meaning

Meaning is influenced by a consumer's previous experiences [2], is context specific and personal. Possessions are an objective manifestation of the self [7] and may help us to reinforce positive aspects of our identity to ourselves, illustrating our values, beliefs and choices as an individual.[2] Attachment research has shown that products can embody memories, and by maintaining a sense of past, help to define and maintain self-identity[15]. Whereas attachment research emphasizes self-expression through product personality [6], for lasting user-product relationships, personal narratives/stories may be important qualities. Narratives, like memories, are exclusive to each individual user [2] and can generate profound sensations of attachment and empathy over time. These qualities are relatively easy to express, which may explain their visibility in empirical research.

The closer our relationships are with objects, the closer our relationships are with people [16] is one surprising conclusion suggested by Daniel Miller. The possession and use of objects is not just a question of inwardly and outwardly focused self-expression, but may be part of our construction as social beings, helping us to represent others and our relationships with them. Objects may also be effective ways of communicating aspects of the self that might not be easy to express. Importantly, the "self" in the title of this theme may also be a collective self, an "us".

It could be argued that all meaning contained in products effectively relates back to the self, but the self in terms of self-definition in the widest sense, and self-continuity [5]. Twitchell comments that the happy consumer makes objects come alive while the unhappy one lets the producer generate meaning [17]. For meaning making to be positive it should be self-generated.

This broad family is interesting as an individual and differentiated experience, as an expressible quality and as a robust contributor to product attachment and probably to emotionally durable design,

3.2 Function

The broad theme of function includes use, doing and making. Many aspects of function overlap with the self area, but are perhaps less narratives than daily rituals. Functions here are seen as active behaviour that may contribute to a sense of self and include some notions of doing and/or engagement. The engagement cluster proposed by Odom et al [14] falls into this theme, describing objects that promote physical engagement with the user during use. Engagement qualities may be found in tools that require mastery or skill. Meaningful tools, defined by Battarbee and Mattelmaki, [18] may pose challenges, involving learning over time and involve personal effort, which may also be linked to the idea of psychic energy investment [8].

In the function area there is also a notion of independence, a certain self-sufficiency and satisfaction in doing. The augmentation cluster presented by Odom et al includes intentional modification, customization, decoration and annotation. All of these being physical actions with, and marks left on, material objects. Continued physical interaction with products seems essential to prolong the impact of a product's special meaning and thus for sustaining the consumer-product relationship [15], through use but also through actions such as care and cleaning behaviour.

Function and doing might also be more indirect, as in the example of prayer beads [13] where manipulating beads aids concentration or meditation. The message carrying capacity of objects, acting as communication short cuts, where objects may speak more easily and eloquently [16], might also be considered a function.

This family may be a meaningful way of reconsidering and enlarging the notion of function.

3.3 Materiality

The term materiality is used as opposed to intangibility and concerns material, tactile qualities of products. Current consumers may be more interested in meaning than material [17]. The increasing awareness of the roles of the different sensory modalities and interactions between them may lead to a shift of focus for many designers away from the physical product to the specific experience that a product evokes [19]. But multi-sensory experience approaches probably should encourage more, and not less, attention to the physical aspects of a product, particularly in the sustainability context.

Product material aspects can easily go un-noticed and often should, as Verbeek and Kockelkoren [20] explain using Heidegger's present-at-hand/ready-to-hand distinction. A product while ready-to-hand is invisible; focus is on the action being accomplished, not the object in hand enabling it. But the product becomes present-at-hand when we return our attention to it, for repair or storage. Products must allow for a return from presence-at-hand to readiness-at-hand if a durable relationship with their users is

desired [20]. This dual status makes understanding the role of materiality difficult, our relationships with objects may be strongest when we are not focusing attention on them.
Schifferstein & Spence [19] highlight the emotional dimension of tactual product experiences, that lack of tactual perception can generate feelings of alienation. Affect-gating is a process in which an organism's affective state changes the kind of sensory input that is privileged to enter perception [21]. The research by King & Janiszewski [21] suggests we are more sensitive to tactile stimulation when in a negative affective state. Tactile stimuli can be sought for reassurance, and may be part of auto-telic experiences such as children picking up and carrying around stones. Autotelic material activity, described as non-instrumental, is an end in itself rather than a means to an end and may be unconscious and seemingly pointless [22]. The example of childrens' stones is also interesting as it also suggests tactile presence and pleasure.
This family may counter-balance notions of meaning, and may be under-explored due to the difficulties in quantifying and expressing material relations.

3.4 Time

The importance of time is presented in the perceived durability cluster proposed by Odom et al [14], objects that seem able to be long-lasting, denoting also notions of trust and persistence. Empirical research [3] showed that attachment to products owned for over 20 years was significantly higher than in shorter time scales. Products potentially accumulate valuable meaning over long time scales. Senses used for processing product information change over time, with visual processing used less.
Other related issues are growing old gracefully and visible marks of ageing on products [2], which can in some cases give value by adding character, a sense of age and stories. Products can and perhaps should evolve[2]. Time is likely to build up familiarity, and mere exposure [23] can give more positive affective reactions. Material products also function as effective markers and materialisations of time.
The time theme is complex and transversal, but also essential in lasting user-product relationships.

4 CASE STUDIES

A simplified version of the frameworks presented in section 2, as well as the four themes presented in section 3 were the basis for a number of different short teaching modules at various levels, for students studying product and services design. The modules have included different combinations of theory, user research and creative design exercises. The most effective modules are described below.
A short module, with 2nd year product and service design undergraduates, included a theoretical presentation, followed by a creativity exercise where key frameworks and themes were given as part of the brief. Students had one day to generate sketch concepts for tangible material products with the capacity to generate durable relationships. In this exercise, initial fears about being able to translate attachment determinants into tangible object attributes quickly proved unfounded. The slight lack of variety of concepts found showed that more time might be needed to identify which aspects are more or less easy to translate as product attributes. This quick creativity approach to introducing the subject is similar to, and matches results of the day-long "charette" proposed by Ramirez et al [24], received very well by students, and seen as having challenged their design thinking about longevity.
In another 2nd year module, each student was asked to interview 2 people in relation to a durable product relationship. Results were presented, discussed and emerging reasons for lasting relationships clustered. Despite being a very short module, the wide diversity of relationships, the variety of reasons for their strength, as well as the diversity of objects to which people were attached was effectively illustrated. Feedback from students was very positive, with the follow-up discussions illustrating students' surprise at seeing aspects of product relationships that they had not previously imagined. Students also were able to compare and refine their ideas on the best ways of conducting in-depth interviews, through a variety of communication media.
A longer module with 4th year service and product design students was in the form of a three-day workshop spread over three weeks. Working in small groups, students were encouraged to choose a variety of user-research methods appropriate for investigating lasting and emotional content in relationships with smart phones. Each student team chose 3 complimentary methods to use and adapt, from an initial selection of twenty. Following theoretical input on lasting user-product relationships, students presented their findings in the form of a user research toolbox and a summary of user-product relation observations. Student feedback suggests that the frameworks and themes presented during this workshop were seen as valuable for understanding a subject they considered both difficult and

important. Students confirmed re-using aspects from this workshop for "sense-making" in subsequent projects, including design projects addressing tangibility/intangibility issues.

5 CONCLUSIONS, FUTURE RESEARCH

Though frameworks and themes presented here are not yet structured into a definitive model, the processing-type framework combined with the identification of a number of key themes has proved effective for exploring lasting user-product relationships in teaching contexts.

General feedback from teaching this subject seems very positive, and a variety of approaches seem equally effective, both short and longer user-research exercises, quick creative exercises and as part of long design projects. These case studies need to be compared to other cases addressing this subject in design education, which was not possible in the scope of this article. Future design teaching and research could also aim to generate more testable artefacts with lasting relationship potential.

The questions and themes the over-all subject exposes; user-product material relations and longer time scales, seem potentially very valuable in design teaching and practice, both in product and service design contexts, and in design for sustainability.

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OLD HOPES THROUGH NEW SCHEMES: A PATH TOWARDS INNOVATION

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ABSTRACT
This paper seeks to provide a method of developing innovative thoughts, theories and ways of doing by unearthing and reconsidering theories proposed as a reaction to the circumstances created by the Industrial Revolution. These theories might not have had the desired impact at that time, but this study offers the option of looking at them through the eyes of the present and merging them with new conceptions and ideologies. In this way, it is possible to generate innovative and practical ways of solving problems that emerged more than a hundred years ago and with which we still struggle. The central purpose of this paper is to prove how innovation can also be found in past studies and thoughts if they are applied in different ways, with new tools and in a contemporary context. Once all these has been stated the main aim or research question of this work is formulated as following: How to provide a way to generate innovative and relevant ways of product development that might generate higher ethical standards within product and industrial design theory, based on hypotheses and propositions formulated in reaction to the Industrial Revolution.

Keywords: Innovation, ethics, design processes, theories, industrial arts.

1 INTRODUCTION

A short but concise definition of innovation proposed by the Encyclopaedia Britannica is an 'effect that brings social change'. The idea of social change can lead to a quite large number of patterns and concepts. The reason this concise definition is nonetheless offered is because it highlights that innovation is not necessarily the formulation of popular, trendy or lively ideas or concepts that might 'take the public by surprise' (who apparently are lamentably less and less susceptible to amazement) [1, 2]. On the other hand, innovation can be a concept that indeed generates, initiates, drives or assists social changes or transformations. Not all ideas are innovative and certainly not all the products within our reach have this specific quality, not even if they are famous or sell in large amounts [3].

This paper seeks to provide ideas on how to address and imprint innovation on the design process by looking, analysing, understanding and implementing theories generated in the late nineteenth century as a result of the industrialisation and mechanisation of labour environments. These theoretical contributions might have a strong historical basis and might seem 'dated' to some. However, research has demonstrated that many (poor) working and environmental circumstances that we find today were generated during this period [4, 5, 6], and, since we have not been able to get rid of or modify them, these theories are still valid and apply to contemporary scenarios [7, 3].

2 METHODS: FINDING SITUATIONS AND PROPOSING ACTIONS

This paper seeks to offer an option within product and industrial design theory, the main foundations of which are constructed on theory found in the literature and archives [8]. This research can be understood as the arrowhead of a larger study that might develop later, as practice needs supporting theories to provide the directions for which way to go and on what to focus [9]. The study presented is divided into two main areas.

First, an overview of the study's context is provided, an analysis of the circumstances that developed during the late nineteenth and early twentieth centuries still identifiable at the present time. These findings were obtained through an archival and bibliographical research that, initially, form a picture of the working circumstances during the Industrial Revolution and then depict the same circumstances but in our times. Second, an analysis shows which circumstances have extended throughout both periods. Based on this analysis, we identify the areas in which our 'effect that brings social change' has to act.

Once the field of change is clarified, then this paper proposes an alternative to how to improve these circumstances, formulated based on theories developed at the same time that the problems first emerged, more than a hundred years ago. Remembering that these theories are clearly not new in our current context is relevant, yet, while they were generated as a response to ongoing problems that also emerged more than a hundred years ago, these ideas have endured until this time. They are as valid as they were in the moment when they were first proposed. The innovative part of this study lies in how to extract these theories, analyse them with the eyes of the present, merge them with current postures and propositions and, finally, implement them in current projects to solve problems more efficiently. All this is achieved by comprehending past and new theories, suggesting examples of projects already being created and, last, providing a proposal for the development of projects.

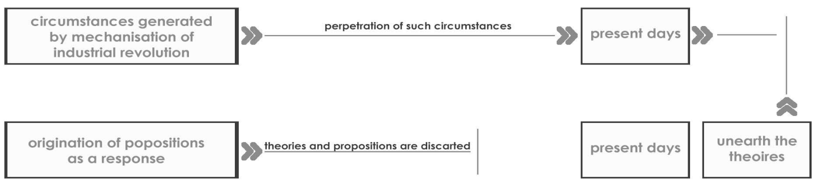

Figure 1. Visual representation of a timeline

3 VIEWS ON HOW TO PROCEED

As previously mentioned, the body of this paper is divided in two main sections. The first exemplifies and describes the improbable circumstances that the industrialisation and mechanisation of tasks created in the Industrial Revolution imposed on the workforce and environment, circumstances that are still visible and that affect a large percentage of the world's population. Once this is clarified, then this paper presents two projects that have sought to improve these conditions through creative, innovative ideas and ways of thinking and doing. Finally, a contribution to theory is offered in order to widen the discussion with a more pedagogical perspective.

Some authors distinguish a very strong connection between works performed in the late nineteenth century with the propositions created by the modernists along the twentieth century. Author Clive Wainwright suggests that the very foundations of the modern way of thinking was highly inspired by individuals such as John Ruskin and Viollet-le-Duc who started differentiating the aesthetic attributes from the functionality of the from [10]. These ideas that emerged in that specific period moulded the way the modernists perceived design, and since the modern approach is still quite visible and has been one of the most important pinnacles of our to-day ways of doing, we cannot deny that at some extend those ideas that emerged on the middle and late nineteenth century still mould the way things are doing these days.

This is just an example that old ideas and propositions can penetrate in the schemes we currently possess by many means, some are the inspiration or the precursors of our contemporary actions, some others however might have systematically disappear or put aside, but that wouldn't necessarily mean that are not valid or proved wrong.

3.1 Areas of change

Automation and mechanisation of different tasks – more concretely, those that emerged as a consequence of the Industrial Revolution's technical and technological impulses among furniture makers – changed working procedures in many ways. These technical and technological 'improvements' were created to help workers and make their exertions easier and more bearable by reducing physical work and the time needed, as well as diminishing the complexity or 'skilfulness' of certain tasks. At least, that was the primary intention. However, inherent in these transformation, harmful situations emerged as well. Work that was initially performed with skill and precision changed to mechanical routines full of boredom and monotony, making workers uncreative and demotivated and transforming skilled craftsmen into mechanised operatives. We can observe that these circumstances have not changed until today, and workers in many sectors of industry, just as they did in furniture making, complain about monotonous tasks, excessive working hours and unfavourable circumstances in working places. Clearly, the automation of activities has not brought more fairness to workers: it has mainly brought greater income to 'owners'. Reflecting on these matters, designers have the opportunity to contribute to changing these patterns by generating projects that incentivise the capabilities and productivity of skilled workers, giving them the opportunity to develop and participate with their imagination and characteristics [11]. This means generating projects that involve the workforce and thinking systematically about their needs and conditions, instead of only relying on them as an assumed and 'de facto' phase of the manufacturing process. As Kropotkin wrote in 1900:

> Must all this skill, all this intelligence, be swept away by the factory, instead of becoming a new fertile source of progress under a better organisation of production? Must all this independence and inventiveness of the worker disappear before the factory levelling? And, if it must, would such a transformation be a progress, as so many economists who have only studied figures and not human beings are ready to maintain? [4]

Human capital has not been the only element affected by this way of producing items. It is of importance to recognise that great damage has been caused to ecological and environmental systems through the economic, manufacturing and distribution frameworks applied since the Industrial Revolution. Kropotkin incisively described this as 'the narrow conception that profits are the only leading motive to human society, and the stubborn view which suggests that what has existed yesterday would last forever'. In 1911, Morris offered a proposition:

> There is one duty obvious to us all; it is that we should set ourselves, each one of us to doing our best to guard the natural beauty of the earth: we ought to look upon it as a crime, an injury to our fellows, only excusable because of ignorance to mar the natural beauty, which is the property of all men; and scarce less than a crime to look on and do nothing while others are marring it, if we can no longer pledge this ignorance [11].

A hundred years ago people were already considering and analysing the great havoc that mass production had on our natural resources. Today, this is a reality that cannot be ignored anymore. Again, this offers a wide area of opportunity for designers to develop intelligent solutions, either by safeguarding and preserving the natural environments that still exist or by taking a step forward and improving those systems that, in most cases, are already damaged or endangered. Proactive efforts have emerged, and many authors have attempted to arouse designers into taking a stand when it comes to addressing these matters. In summary, it can be stated that designers can choose to generate projects that preserve or promote ecological considerations, among which are ideas on how to reduce materials and eliminate packaging, shipping and transportation, as well as relying on controlled sources, markets and working environments [12, 13, 3].

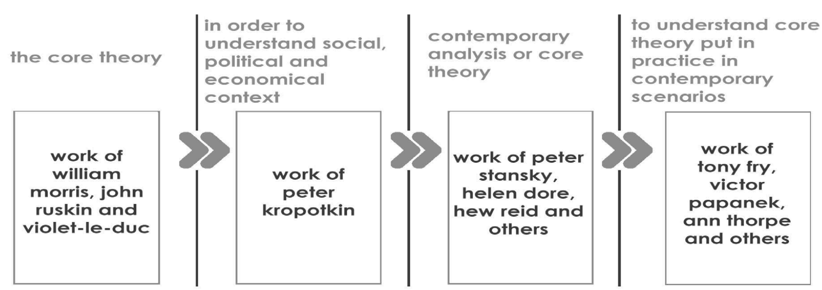

Figure 1. Graphic displaying the use of bibliography

3.2 Two projects as an example of innovation in design

In the next subsection, two projects from two different designers are presented and explained. These projects were selected because they reflect the ethical qualities presented by the theories emerging in response to the Industrial Revolution. These examples are related to the theory and methods previously described and they will be useful in the discussion and conclusions of this study.

3.2.1 Safeguarding local environments and means of production

The Eco-Recliner of British designer Simon White appears to be a simple, humble product. As stated earlier, small but well planned and executed projects can lead to large impacts. This recliner's innovation does not lie in its form or aesthetics; it is stated in the manufacturing methods and the selection of materials. When this project was developed, it was a pioneer in only using protected, regulated and locally extracted ash wood in its construction. The manufacturing of this product ensures energy and resource consumption is reduced, and it can be performed in considerably smaller environments. This project safeguards local environments and brings work back into the hands of craftsmen and small producers, instead of being mass-produced in order to put relevance in the hands of these individuals again [14, 15].

As a response to the industrialisation seen in his time, Morris long ago proposed local markets and crafted means of production be established as a pathway towards workers' well-being and ecological sustainability [10]. Because of increased, mainstream patterns of mass production, these ideas had little impact in his time, and sometimes were considered mere romanticism [16]. However, now that people's mind-set and circumstances is different, these kinds of approaches might have a better ground on which thrive and work. As we can see from this comparison, White has not 'invented' or created the theories or frameworks of the characteristics he decides to imprint onto his projects, but this could be an example of how an innovative designer sees the potential of some 'old' ideas as for example the utilisation of craftsmanship as a mean of production, and puts them in practice with positive results.

Something that might be important to take into consideration is the fact that the concept of locality was already present in times as the late eighteen century, people in that time were already talking of using local materials, sources and even abstract forms such as colours to generate pieces of use and of architecture [10]. Ideologies of individuals as Sir Joshua Reynolds and William Wordsworth were collected and used by John Ruskin, then these ideas passed to Morris and the chain of knowledge can be then traced until our time.

3.2.2 An aware and conscious designer

Another contemporary example is the more conceptual work and approaches of British designer and naval architect David Trubridge. He invites us to think about the way production in design has led to unnecessary consumerism. He questions the ethical considerations involved in the way we put things on the market and challenges designers to consider if they need to put yet another 'product' out there in a market that is already overloaded with goods and objects – with invented necessities and artefacts of 'pleasure' but not 'usability'. He criticises the impact and trail of 'litter' a person leaves behind when he or she acquires and disposes significant amounts of goods throughout his or her life.

Trubridge is innovative because he sets opinions at the core of what a designer is supposed to do. He puts in doubt the essence of product and industrial design and invites the people involved in this area to criticise and consider other aspects rather than the expected impulse to sell. Sometimes, designers are so concentrated on solving 'problems' that they fail to analyse if the problems are actually there or if the 'solving' of that problem would cause even more issues.

These theories and thoughts appear to be strongly related to environmentalism since they seek to generate change in the current means of production and distribution [17]. Again, we focus on diminishing the load of manufactured goods to relieve pressure and bring more virtue on and to the structures that provide these goods: nature and human hands. Trubridge not only pleads for an aware and conscious public and consumers, he also seeks to promote this in designers because he believes his duty lays in incentivising these changes.

4 A PEDAGOGICAL CONCEPT

These theories this discussion is based on certainly cannot act by themselves in this current and quite different environment. They have to pass through the filter of this new reality and somehow be moulded to meet new requirements.

One point that can be expanded upon is related to intermediaries in design production [6]. Designers would more easily and more effectively work on more simple schemes where the maker and the user are close and have an intimate relation, one knowing the needs and desires of the other [5]. When mass production started to be the main way of production, secondary industries started to emerge between users and producers. These intermediate industries created a bigger distance between the two groups that formerly had to be necessarily close. This separation developed into negative circumstances for users because, since the intermediaries had to receive some income, the products would become more expensive. This process also affected the producers in important ways. In order for these intermediaries to survive, the producers had to lower their prices. Consequently, the workers were the ones that suffered the most [4, 6]. In addition, since the close connection between them was lost, it became more difficult for one group to identify the needs and understand the conditions of the other. Thorpe writes that, 'with global sourcing of lower-cost materials and labour, substances banned in "developed" countries can be used in "developing" countries and then enter developed countries as finished products' [3]. The theories described above consider the benefits of bringing production once again as close as possible to the users. Both parties will benefit if projects with these characteristics were to be developed, reducing the role of intermediaries such as distributors, shippers, retailers and sellers. Fuad-Luke suggested that:

> Green design has a long pedigree and before the Industrial Revolution it was the norm for many cultures. Goods like furniture and utility items tended to be made locally by craftsmen such as blacksmiths, wheelwrights, and woodland workers, from readily available local resources. [12]

The issue of local materials is also something that has to be seriously considered. If designers would use only (or mostly) materials found in close localities, the large market of materials distribution would be reduced, and, with this, the demand for non-protected or endangered raw materials would fall. Design would mould and adapt to the circumstances of the places where it is performed, not as sometimes has been the case – the other way round. The usage of mainly local materials would, quite importantly, confer on the design a uniqueness and particularity that would be unmatched, generating beauty and singularity in projects [1]. Thomson stated that:

> The Nordic Ecolabel, Blue Angel and EU Ecolabel are used to mark products that meet extremely high environmental requirements based on lifecycle assessment (LCA). This includes an assessment of raw materials, production, use and disposal, fair trade, promotes better prices, decent working conditions, local sustainability and fair terms for farmers and workers. [13]

Technology is not something that needs to be seen as opposed to these matters. It is exactly the opposite. As explained previously, all technological advances that occurred in the Industrial Revolution was meant to help workers and to make his tasks more bearable. That it did not accomplish this is because of the greed of, and misuse by, some segments or entities within the production processes [5]. All the technological tools the modern world possesses can be put to the service of people and users. The more production adopts these approaches, the more these theories can be validated. Two positive and supporting perspectives from two different authors can be added here. One said, 'New technology is taking production back to the small-scale craft user and placing it in the hands of the consumer' [18]. The second stated, 'While the word [craft] may have disappeared from some visible marquees, the good news is that the material concerns, processes and transformations that craft addresses are enjoying larger and more usually literate audiences than ever before' [13].

5 DISCUSSION

It might be possible to start the discussion by addressing the point that talks about the importance of being able to understand theory and what it means in current contexts; it might be that it's possible to track every single current of design throughout all our history in today's design and doings, and this can be by various means, it might be that some product in particular was conceived by getting inspiration on something previously made. Author Clive Wainwright states that architects and designers consciously and unconsciously apply past theories to their works even if they might have forgotten their influence and relevance.

It might be that these initiatives that might seem little, are the actual area of change and of opportunity for a greater change. If little efforts are summed up it may be possible to generate a big transformation.

It is also a certainty that all this knowledge has to be put in practice within educational environments, if students and professors together employ these knowledge in order to generate a sense of consciousness in design education, the topic would become more available and familiar, therefore more used. A broader research has demonstrated that if students are not put in contact with the imperatives of ethical management, in the name of social wellbeing and the preservation of environmental and cultural aspects, it would likely be difficult to interiorise it when performing their advanced studies or their professional activities.

6 CONCLUSION

This paper has addressed, first, some problems that exist within the production segments of the design industry. Second, it offered some solutions that designers have developed in order to fight these problems. Finally, a further solution was discussed, considering more carefully the implications that affect us, and possible ways to solve them. As we have seen, increasing numbers of people are proposing projects like these. They can start as small, humble ideologies, but as discussed throughout this paper, if they are properly put into practice, they can generate and lead to great transformations. Another point that was emphasised is that innovation can be just around the corner: inventing a new radical breakthrough is not necessary to make a project innovative. Inspiration can come from work done by others in the past but implemented in different, new situations and visualised in new contexts, generating effective changes.

In an encouraging trend, people have started to take action in various areas of design. Whether in the field of education, production, design development or research, we must find help in every tool we have at hand. This paper has shown ways in which designers can feasibly take 'past' theories as a basis for generating positive results, instead of generating completely new ideas from scratch. Doing this can be perceived as making new contributions and using a different approach that can be as useful and innovative as other existing approaches. Much work and knowledge has been generated throughout time, and designers need to unearth this, categorising what we can use and then using this and putting it into practice to achieve the greater good.

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DESIGN STUDENTS AT THE CROSSROADS OF ADAPTION AND SELF-WILL

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ABSTRACT
One challenge in design education is that design students should develop a deliberate personal stance. Recent discussions on design education appear to be focused either on the provision and adaption of methods and toolboxes or on issues of apprenticeship. In this paper we argue that theses perspectives entail rather simplistic ideas of the designer´s agency. We therefore outline a third perspective that highlights the transformative nature of practice in educational settings and provide a relational concept of style as a dynamic expression of a personal stance. Educational situations are not confined by the interactions between the student and the teacher but inevitably also mirror the articulated or presumed expectations of other actors, be it users, clients, fellow students, future employees, and other stakeholders. As a consequence the student has to find a way to cope with the polyphony of expectations and act on multiple playgrounds simultaneously. To illustrate how the quest for style might materialize in an educational setting, we present examples from a field study. Based on these examples we discuss implications for design education.

Keywords: Design studio, student-centred, reflexive fellow player, style.

1 INTRODUCTION

Becoming a designer requires more than the acquisition of reproducible knowledge, competencies, and skills. Furthermore, becoming a designer is more than the practical capacity to create viable solutions in response to a design challenge. Taking up a holistic view of design, designers not just respond to existing needs with and through their products but envisage and shape future usage scenarios (cf. [16]). In doing so they are unavoidably engaged in transformative transactions with the social and material world. Hence design students should develop a deliberate personal stance on the potential impact of owns actions and the resulting responsibilities.

Even though the societal impact of design has been broadly acknowledged in the design community, recent discussions on design education however appear to be focused either on the provision and adoption of methods and toolboxes or on issues of social participation, apprenticeship, and enculturation. While both of these directions provide essential input for the field of design education, they do not fully account for the transformative and transactional nature of design as a socio-cultural endeavour. Even though methods are to some extent generic in that they are supposed to be of use in a variety of situations they are by no means neutral, as they always have to be enacted and made sense of by the actors involved. The conception of design education as a form of social participation and enculturation into a particular professional community on the other hand easily tends to present professional practice as a given rather than a continuously evolving nexus.

Against this background, the intent of this paper is to outline a student-centred perspective on learning and personal development, aiming to provide an answer on how students might develop a professional yet also personal stance towards design. Rather than foregrounding the acquisition of particular skills or being able to engage in established practices, we state that the primary challenge for design students is to develop a viable stance with respect to the polyphony of expectations they see themselves and the products of their work confronted with. The students are not only confronted with their teachers' expectations, already reflecting a certain view of design, but also with the articulated or presumed expectations of users, clients, fellow students, future employees, and other stakeholders. Furthermore, students anticipate expectations of their educational institution as well as the design community at large. The students cannot accommodate all these, potentially conflicting, expectations by conformation but have to advance a personal stance.

The contribution of this paper is meant to be threefold. On a theoretical level we introduce a practice-oriented concept of style, accounting for its stabilizing and disrupting effects. On a more practical level, our intent is to make the concept of style operational for design educators and provide empirical examples. Finally, we hope to encourage students to rethink their own role and become reflexive fellow-players.

In the following we critically discuss two currently prominent perspectives on design education, the one focused on methods and toolboxes and the other geared towards the mastery of established or best practices. Based on the identified shortcomings, we then introduce a practice-theoretical position and the notion of a reflexive-fellow player [8] and advance a relational concept of style as a dynamic expression of a personal stance. To illustrate how the quest for style might materialize in an educational setting, we present a series of case examples from a field study on the practices in a design studio course in the field of interface design. Finally, we discuss the implications for design-education.

2 TWO PERSPECTIVES ON DESIGN EDUCATION

In recent discussions on design education two main perspectives can be identified. The former puts emphasis on the purposive utilization of methods. The second positions design education as a form of apprenticeship aimed at the mastery of established practices. In educational practices both perspective are enacted in a variety of ways and often even combined. Below we try to pinpoint some of the inherent problems these perspectives are facing when seen in isolation. This separate description is used as a strategy to emphasize blind spots in the two perspectives from a practice-oriented view.

The first perspective is driven by the idea, that design in essence can be understood as a methodological endeavour, which favours certain methods and ways of thinking. Respective methods can be taught and are generic enough to be of use in a variety of situations. Consequently there is an interest in teachable methods designers can make use of in the design process. Respective approaches can be focused on the management of the overall process (cf. [11]) as well as on the particular methods used in the course of the design process (e.g. [9]). While in fact methods and tools provide crucial resources for those engaged in design, the perspective tends to blur the inherently situated nature of design, as methods and tools are conceived as context independent means at the designer's disposal. As pointed out by [3], the paradox of this perspective is "it that it relies upon the articulation of methods for work but those very methods are never a complete or accurate description of work practice" (p. 45). Hence an overemphasis on methodology downplays the fact that respective commitments shape the discourse on design and the relationships between the different stakeholders involved. The idea that methods could be invoked arbitrary and transferred from one context to another and that they are just neutral means to an end is misleading as it ignores that these are always enacted and made sense of in the light of the on-going practice.

The second perspective emphasizes the disciplinary aspects of design as a profession drawing on notions of apprenticeship and mastery. This perspective is closely related to the design studio model (cf. [10]), which is at the core of architectural education [1] and also prominent in other fields of design education. The relation between teacher and student in these settings often resembles a master-apprentice model. This implies that the teacher as an expert and representative of the professional community has the knowledge the student is supposed to acquire and incorporate him/herself. The respective design knowledge is conveyed, among others through various forms of feedback, such as recurrent design crits. The conception of design education as a form of enculturation gives room for implicit forms of knowing and the contingent nature of professional practice that develops over time. However, the model involves the danger to cultivate asymmetric (power-)relations between teachers and students (cf. [5]) and to hand down professional practice as a given rather than a continuously evolving nexus of doings and sayings that is itself shaped by and shaping social order. Putting emphasis on established professional practice blocks sight for the different ways design is and could be practiced as well as the question of how to critically reflect and improve professional practice.

Our main concern with these perspectives is that both of them entail rather simplistic ideas of the designer's agency. While the first perspective locates agency primarily in the person of the designer and downplays social and cultural contingencies, the second perspective locates agency primarily in the community of professionals providing no direct account on how individuals contribute to the advancement of practice. In the following, we therefore outline a third perspective that highlights the transformative nature of practice and puts the student at centre stage.

3 TOWARDS A STUDENT-CENTRED PERSPECTIVE

To allow for a more dynamic understanding of agency in the design process we build on a practice-theoretical understanding of human action and especially the idea of a reflexive-fellow player as suggested by [8]. We then use this notion to advance a relational concept of style and outline its educational implications.

3.1 Practice Theory and the Reflexive Fellow-Player

Following what has been called the "practice turn in contemporary theory" [14] the notion of practice has been suggested as a basic unit of analysis in the field of design (e.g. [15]) as well as in education (e.g. [7]). Practice theoretical accounts differ from both structuralist and individualist accounts of human action in that they assume both social phenomena such as science, power, organizations, and social change but also psychological phenomena such as reason, identity, learning, and communication to be bound to practice. They assume "practices to qualify as the basic social phenomenon because the understanding/intelligibility articulated with them (perhaps supplemented with normativity) is the basic ordering medium in social life" ([12], p. 284). In providing a non-intentional account of human action, this perspective transcends the dichotomy of subjectivism and objectivism. Meaning from this perspective is inherently bound to the nexus of doings and sayings the actors are engaged in.

Practices are inherently social, as their very structure emerges from repeated interactions among the participants involved (cf. [12]). Yet, these structures are not static, but constantly evolve, as they are re-enacted in concrete doings and sayings of participants somewhere in objective space and time (ibid). Due to their evolving nature the canonical practices of certain community always coexist and are potentially challenged by non-canonical ones (cf. [2]). From a participant's perspective established practices entail certain rules that help to form joint expectations regarding what is appropriate or inappropriate in a certain situation. However, these rules do not provide a fixed set of admissible moves but require the participants to actively interpret and realize them in light of particular situation they are facing. Being able to engage in a practice together with others and to act in a way that others can understand is therefore more essential than simple compliance with the rules [6]. As a consequence, the aptness and viability of a certain move cannot be fully assessed based on pre-established rules but essentially depends on its uptake in a particular situation.

If we apply this perspective to an educational scenario such as the design studio, the prerogative of interpretation cannot be simply attributed to the teacher or the student. From a practice-theoretical perspective the situation is similar to a game in which the rules are constantly re-enacted but also altered by the very moves the teacher AND the student are making. The educational situation hence brings forth its own practice. Yet, the educational situation is not confined by the interactions between the student and the teacher but inevitably also mirrors the articulated or presumed expectations of other actors, be it users, clients, fellow students, future employees, and other stakeholders. As a consequence the student has to find a way to cope with the polyphony of expectations and act on multiple playgrounds simultaneously. The situation hence is of a kind where the student cannot simply draw on a method or established practice but has to position him/herself in all these games. S/he can neither act in compliance with all these expectations, as these are potentially conflicting, nor can s/he simply dictate the rules, as s/he cannot step out of the game.

Against this background [8] has introduced the figure of the "reflexive fellow player", an actor oscillating between adaption and self-will, between adjustment of actions towards circumstances and restive scepticism. The "reflexive fellow player" is aware of the fact that s/he is inevitable involved in a variety of on-going practices, but also recognizes that the rules of the respective games are not fixed but can be challenged and bent by every new move that is made. The "reflexive fellow player" provides an alternative model for the becoming designer. S/he is neither a trainee primarily aimed to get proficient in the tools and methods of the trade nor an apprentice aimed to master a set of established practices, but a person that has to develop a personal stance towards the practice of design. From an educational perspective the figure of the "reflexive fellow player" shifts focus towards moments in which students challenge and advance their own practice. This process starts when students realize that their own doings and sayings are constitutive for the situations they are facing, when they realize that their actions are shaped by but also shape the social context there are engaged in. This kind of reflexive practice is constitutive for the concept of style we develop below.

3.2 Style as a Relational Quality

The concept of style has a long history in the fields of arts and design. It has primarily been used to differentiate certain works of art and design, either by period and region, by groups and brands, or by particular individuals. Depending on the perspective chosen, style has been seen for example as an expression of societal and cultural values, economic forces, or personal traits. However, irrespective of whether style is attributed to a certain culture, brand or person, it usually conceived as a function of the amount of common features in a set of works [3]. In this sense style is understood as a form of repetition and constancy.

However, Walker [17] already argued that the concept of style as something that is primarily rigid and closed tends to lose sight of the fact that style also provides a means of communication and identity formation created and reproduced in social contexts. In a similar vein Wenger 0 pointed out that style is closely linked with discourses "by which members [of a certain community] create meaningful statements about the world" (p. 83). If we assume that the social contexts and discourses in which the participants find themselves in are constantly evolving and inherently polyphonic, a conception of style based on repetition and commonality appears limiting, as it provides no account of the dynamicity of practice and personal development.

Therefore, we suggest reconceptualising style as a particular quality of the relation between an actor and the practices s/he is involved in. More precisely we understand style as reflexive practice, as a reflexive exploration, appropriation, and transformation of situations, resources, and discourses. The development of style hence can be seen as a deliberate and on-going engagement and confrontation with one's own practices in and through which the actors develop a personal yet dynamic stance. Style is neither a competency, a quality of the product nor the process itself, but a reflexive response to the situations the actors find themselves in. Style in this sense signifies a relation between an actor and a practice that is neither dogmatic nor arbitrary. It is not dogmatic in that it is sensitive to the particularities and dynamics of the situation and it is not arbitrary in that it does not relativize value dispositions and the strive for a worthwhile future.

Conceiving style as a relation provides a new perspective for design education, as it transcends both the acquisition of methodological know how as well as the mastery of established practices. Rather it calls for settings that provide fertile soil for the development of style, prompting students to realize the ways in which their practices and the products shape and are shaped by social and cultural context out of which they arise. The development of style thereby relates the students not only to their products and the educational setting, but also to the envisaged users and their practices, to peers, clients, stakeholders, as well as to the professional community at large.

4 CASE STUDY

The above-introduced concept of style can be used by practitioners to shed light on the various ways in which students engage with similar situations. To illustrate how the quest for style might materialize in an educational setting, we present case examples from a field study. The primary intent of the examples is not to assess a particular practice as good or bad, but to raise awareness and sensibility for different enactments and how these shape the educational situation.

The case examples are taken from an extensive field study in a design studio course on interface design at the Muthesius Academy of Fine Arts and Design, carried out by the authors in spring 2013. As part of the study, more than 90 individual feedback sessions held by 17 students, the instructor and a research assistant, have been followed throughout a period of 14 weeks. Under the overall theme "simulation/simulator" the students were asked to define and carry out individual projects.

These feedback sessions in the design studio setting recurrently required the students to update the instructor and the research assistant on the progress made since their last meeting and to pinpoint the issues the students wants to discuss or get feedback on. Furthermore, the sessions typically required the participants to synthesis the results of the discussion and plan for the next steps.

Example 1: The student is trying to make synesthetic phenomena tangible for the user. She is experimenting with combinations of acoustic colour, smell and movement patterns. At the time of the feedback session the project is already well advanced and the concept idea has materialized in an interactive prototype. As the feedback session starts, the student provides no introduction. Neither does she explain the steps that led to the realization of the prototype, its mode of operation, nor does she utter any themes or questions she would like to discuss. Instead, the instructor immediately starts to try out the prototype in order to test the experience provided. Afterwards the instructor goes on to ask the students how she built and programmed the prototype. The conversation finally turns to the planned project presentation at the end of the term.

Example 2: The student is working on a simulator for the bonding of atoms to be used in chemical education. For the feedback the student has brought in a mind map, a couple of hand drawn sketches, a paper-mock-up of the input devise as well as digital 3D renderings visualizing the bonding process. The student updates the instructor on what he has done the last week, referring to the various design artefacts he had created along the way. Following up on the introduction, the student and the instructor engage in a discussion on the scalability of the concept in a classroom setting and interactively play through a hypothesized educational application scenario. After about 25 minutes the instructor takes a look at his watch and starts to summarize the issues he deems most important. The student takes note in the meanwhile and closes the session by summarizing the upcoming tasks to be carried out.

Example 3: The student is working on an interactive installation aiming to engage two users in the joint creation of a soundscape. At the beginning of the feedback session the student provides the instructor with an overview of the topics he would like to discuss. Drawing on the metaphor of a menu, the student presents these topics as a multi-course dinner, he would like to go through with the instructor. As suggested, the session starts with an overview on the recent accomplishments of the student and then moves on to a try-out of two prototypes by the instructor. Afterwards the student and the instructor, to identify potential directions for the advancement of the student's project idea, discuss the prototypes. At the end of the session the instructor notes to the research assistant that this has been one of the most beautiful introductions to a feedback session, ever.

Even though the educational arrangement is quite similar in all the examples, the three students frame the situation quite differently. While the student in the first example is rather passive and reactive, in that she provides not account on what she has done or would like to discuss, the student in the third example is quite proactive and actively sets up the feedback session. The student in the second case provides an update to the instructor and also identifies those issues that he would like to discuss, but also invites the instructor to comment on and add to the suggested agenda.

With the way the students open up the feedback session they, at least implicitly, indicate how they expect the session to be enacted. They also assume or refuse responsibility for the situation. In leaving the floor to the instructor, the first student to some extent refuses responsibility while the third student explicitly claims responsibility both for the contents as well as the procedure of the feedback session. The second student, in turn, positions the session rather as a joint endeavour in which he is interested in the instructors contributions.

However, even though the students frame the situation quite actively, even when acting passively, the actual enactment of the feedback session inevitably also relies on the instructor's responses to the students' moves. He is neither forced to take the lead in the first case, or be guided in the third one, nor does he have to accept the role of an active contributor in the second case. Rather in the way he responds to the students' moves he signals it to be an appropriate or inappropriate move or even declare it to be an exceptional one.

The examples provide a glimpse into the variety of ways in which students might respond to and engage with the feedback sessions in a design studio course. It becomes apparent that, rather than being a static container predefined and orchestrated by the instructor, the educational situation is a joint performance of the students and the instructor. As such, it provides an arena in which the participants constantly learn about but also probe into what are deemed to be appropriate moves and what are not. The instructor allows the students space to explore style as a reflexive response to the feedback setting rather than predetermines certain methods or establishing best practices.

5 IMPLICATIONS FOR DESIGN EDUCATION

We have argued that style is not a static attribute but a quality of the dynamic relation between an actor and the practice s/he is involved in. The development of style is an open-ended process emerging from on-going practical engagements. Based on a set of example cases we have shown that one and the same educational setting can be enacted in quite different ways, enactments in which students' personal stances take shape and evolve.

As a relational quality, style cannot be traced to a single situation, but at best becomes apparent as a transforming pattern across a series of situations. Yet, in each situation we can spot the expectations the actors bring to bear and how others take these up. Turning focus on how students stick to or reinforce particular framings of a situations and whether they urge for canonical or non-canonical

practices we can get some idea on whether students insist on some established practice, whether they accept any external demands without resistance or whether they try to broaden their scope of action in response to the particular situation they are confronted with.
The concept of style, as introduced in this paper, has several important implications for design education. First, it forces us to reconsider the prime objectives of design education. Neither the skilful command of tools or methods nor the mastery of established practices can be an end in itself. Rather, design education needs to empower students to become "reflexive fellow players" and engage in the constant advancement of design as social and political endeavour. Second, the educational situation has to be reconsidered as a performative encounter in which students and teachers (re-)negotiate the appropriate moves to be taken. The question hence is less on what it takes to be an excellent teacher or which approaches are most suitable to train a particular skill, but how can situations be created that enable students to engage in both canonical and non-canonical practices. Finally, it also calls for a shift in research on design education from generic models and best practices towards the situated nature of educational encounters that are not only framed by teachers and institutions aspirations but also by the students expectations and understandings.

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Chapter 12

Project Based Learning

MAKE YOUR BED AND LIE IN IT! LEARNING TO TAKE THE CONSEQUENCES OF DESIGN DECISIONS IN AN ENGINEERING DESIGN PROJECT

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ABSTRACT
In many design assignments engineering students do a lot of paperwork. But on very rare occasions during their studies they should also build and test the appliances, products or machines they have planned. In this paper, the authors report on a project-oriented 'design-build-test' learning experience that accompanies lectures on Engineering Design during the third semester of a Bachelor degree programme in Mechanical Engineering. In the past academic year, students at *DHBW Baden-Württemberg Cooperative State University* were asked to design a winch for launching non-motorised model aeroplanes (gliders). The ground-based winch should be powered by a cordless drill. Instead of designing everything 'from the scratch', the parts for the winches should be entirely selected from a comprehensive supply parts catalogue, meeting a given budget. This allowed to go through all development phases from conception to functional testing within only six weeks without causing major capacity constraints to the faculty's laboratory. For practising communication skills, students from three different classes and two campuses were teamed up in groups. The project also involved new techniques for classroom assessment. For example, students partially got graded for easily accessible design-related parameters, like cost and assembly time. For determining the latter, the students shot an uncut digital film ('video selfie') which they uploaded on the virtual learning environment *Moodle*. The actual launching of the gliders will be organised outside the course in form of a competition next summer.

Keywords: Design-build-test experience, student projects, engineering design, problem-based learning, orientation on competences, communications skills.

1 MOTIVATION AND AIMS

In contemporary engineering education Crawley [1] observes 'a seemingly irreconcilable tension between… the ever increasing body of technical knowledge that… graduating students must command... [and the] wide array of personal, interpersonal, and system building knowledge and skills that will allow them to function in real engineering teams.' In response to this shortcoming, the *CDIO* initiative – an international educational network – formulates that the chief concern for engineering faculties should be to form students that are able to 'conceive, design, implement and operate real-world systems and products'. In other words, 'tinkering' [2] becomes 'academically acceptable' again and regains its significance in engineering education.
In this paper, the authors

- report on their concept of a student design project that they have developed and refined over the last five years
- comment on promising outcomes and point out current deficiencies
- want to share the experiences made in this design-build-test-oriented project course with other (passionate) lecturers

1.1 Projects that dig deeper

Design assignments often are pure paperwork – even when real-world problems are studied (problem-based learning). Within the field of engineering design many problems rest hidden under the surface. Especially for novice designers, many of these problems must be experienced. For example, from technical drawings it is not obvious for beginners how much effort it can take to assemble an 'oddly-executed' design.

1.2 The role of lecturers: Keepers of the Holy Grail or facilitators for learning?

Even though the generation of students that enters tertiary education nowadays has grown up with project-oriented learning, some students still 'cultivate' archaic and simplistic reasoning about what an assignment should look like. Many lecturers will recognise this mental model about teaching and learning that they encounter nearly daily. However, often students assume that their lecturer gives them problems, where he perfectly knows the answer, like a paper chase game (hare and hounds) for long solved problems. In this restricted view, the assignment just serves as a test if the student has paid attention in the lectures about what the teacher thinks the right answer is. One of the hardest lessons in design-related subjects is: There is no (absolute) right or wrong design. Solutions only tend to be better or worse (with respect to given conditions).

1.3 Developing engineering responsibility

Coming from a school environment where passing exams is the measure of achievement, undergraduates often still have a vague concept of 'professionalism' [3]. Student projects can be a crucial point in the curriculum where students develop a 'deeper understanding of a basis for decision making'. Thus, determining the transmission ratio is not just an abstract number in a student report that is buried in the files but becomes a strategic question for students that decides whether the own design performs better than that of other teams or not. Design-build-test experiences are also a good opportunity for studying the consequences of own design decisions and for learning to feel responsible for these. Having experienced this mechanism once deeply (at a complex but still surveyable scale) is the critical step over the doorsill for scrutinising the own responsibility and duties in the larger context of 'engineering ethics'.

2 COURSE DESCRIPTION AND DESIGN BRIEF

Over the last five years the authors have developed and refined a project course at *DHBW Baden-Württemberg Cooperative State University*. The student project accompanies a lecture on Engineering Design in the third semester of a Bachelor degree programme in Mechanical Engineering.

A good (problem-based) assignment fits on less than a page: In the past academic year, the students were asked to design a winch for launching non-motorised model aeroplanes (gliders). The ground-based winch should be powered by a cordless drill.

2.1 Immersive character

The main goal of the course is to 'fence in a playground' where the students should forget about the academic laboratory conditions in which they are acting and instead immerse totally in the project. Letting teams compete for the best solutions helps to blur the boundaries between academic studies and real-world problems [4, 5].

2.2 Against the clock

Another key element of the project course is its timeline. It allows the future engineers to experience the whole product development process in fast-motion. Within the extremely short period of six weeks, the students pass through all stages from requirements analysis, conception, the actual design, over the purchase of the parts to the assembly and testing of *their* product, cf. the project plan in Figure 1.

2.3 Configuring standard parts, instead of designing everything from the scratch

A deeply distressing experience for the students was when they were told that not everything should be designed 'from the scratch'. Instead, the parts for the winches should be entirely selected from a supply parts catalogue (Figure 2) with more than 4,000 pages. Although even turned shafts could be ordered readily by a part number, many students reacted with the feeling that their design freedom has been curtailed considerably. It sounds trivial to order parts by a part number from a catalogue, but up to 12 % of the items in the parts lists were not correctly indicated by the teams. A pedagogically particularly valuable detail is, that it was not the lecturer but a sales representative who pointed out the mistake to the students.

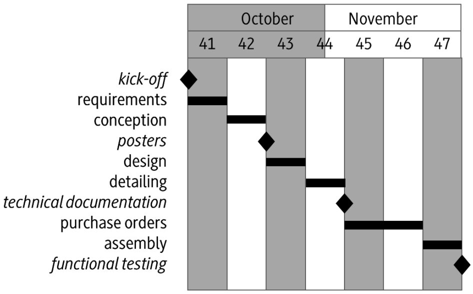

Figure 1. Project plan

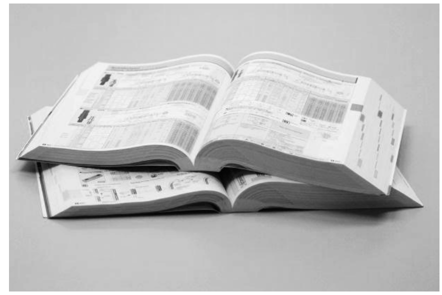

Figure 2. Supply parts catalogue

Figure 3 exemplarily shows a concept of a student team using a simplified graphical representation for kinematics as specified by ISO standard 3952 [6]. Figure 4 reproduces an assembly drawing of a 'configured' design. The short delivery times (that range between two days for standardised parts and eight days for machined parts) allowed to continue seamlessly with the building phase, cf. Figure 6, without major capacity constraints in the faculty's laboratory.

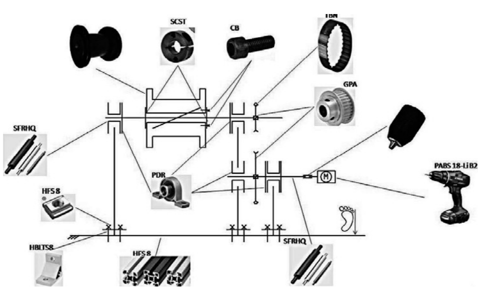

Figure 3. Drive concept of a student team

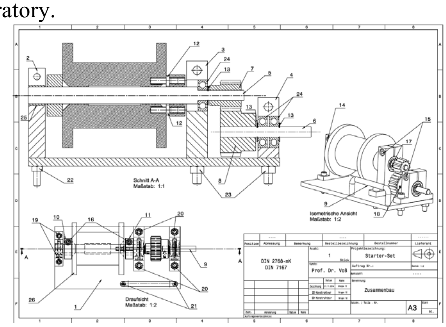

Figure 4. Technical drawing of a student team

2.4 Fixed budget

Exactly as in real-world projects, the budget in the student project was restricted. But for keeping it simple and easy to verify, only the costs for buying parts were accounted. Every team disposed of a budget of € 250 (gross amount).

3 COMMUNICATION

One of the major abilities that engineers need in real-world situations is communicating with others.

3.1 Distance communication

For practising these skills, students from three different classes and two campuses were teamed up in twelve groups of six to seven. The classes did not know students from the other classes before. The distance between the campuses is 215 km as the crow flies. In the course of the project, students at one site met regularly face-to-face, between both sites purely distance telecommunication (group meetings with Skype, e-mail, telephone) was used. As expected, in conflict situations (e. g. when own expectations were not met) students complained mutually about their teammates, especially about those from the other campus. In a similar interregional and international collaboration project, Advani, Frost et al. [7] also describe a negative impact on group dynamics that they attribute to the predominant use of asynchronous modes of communication.

3.2 Virtual Learning Environment

The project course used the open source web-application *Moodle* as a communication platform. All announcements concerning the project course were made in the news forum section. The students had to upload all submissions on *Moodle*. This made it easy for the teaching staff to control deadlines. The teaching staff also tested alternative techniques for classroom assessment. While assembling and testing their winches, the students shot an uncut digital film ('video selfie'), cf. Figure 5, which they uploaded on the virtual learning environment *Moodle*. The assembly time was marked on basis of that video. In order to prove that the winch is operative, the teams knotted a light object (a glove or a pencil case) at the end of the bobbin and pulled it over some meters on the floor. The technical side of handling large-sized files did not cause any problems to the generation of 'digital natives'.

Figure 5. Assembly video of a student team

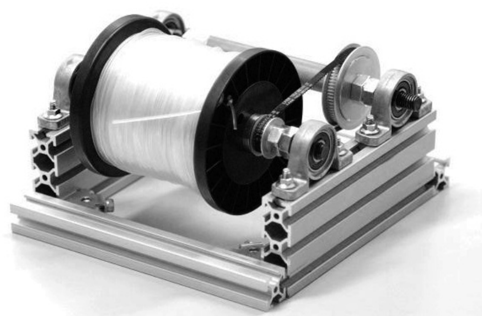

Figure 6. Example of an assembled winch

4 COURSE ACHIEVEMENTS

Overall, the students obtained excellent results in the project and surpassed the lecturer's expectations by far. Through the new setup of the project, the students seemed to be motivated in a high degree and always handed in the due documentation on time. Compared to earlier cohorts, also the technical drawings were much clearer.

4.1 Rebound effect on performance

One of the aims for restructuring this project course has been to give the students a quicker feedback on the results they have produced. In the past, the students worked independently on their project during the semester and wrote a comprehensive final report that was due five weeks after the end of the semester. The reports often were exuberant and imprecise in style and therefore hard to read and correct for the lecturers. The dialogue between the class and the lecturer mostly engaged in the post-exam reviews and degenerated into a haggling for better marks which did not permit a qualitative feedback. And when the class and the lecturer met again in the next semester, everything was forgotten and they had other things in mind. Therefore, a number of milestones were introduced where the students must hand in partial results, as an order list or an assembly drawing for example. Thus, it is easier to outline for the lecturers what they actually want their students to work on while the students do not get constrained in their design freedom.

For marking the students' performance in the module *Engineering Design* in the third semester, the project mark is balanced with the written examination on the lecture using a half-half weighting. Unexpectedly, the overall performance of the current cohort in the module suffered from a strong rebound effect. Since the students got an instant and detailed feedback on their performance in the project, seemingly many of them felt (too) 'safe' for the written examination and did not revise properly. The outcome of the written examination dropped in unimagined depths. More than half of the students fail to reach 50 percent of the maximum score in the written examination, cf. Figure 7. The usual share in this unit is 10 to 15 percent. Of course, the challenge for optimising the project will be about how to give detailed qualitative feedback without inducing a counterproductive behavioural response.

4.2 Cart horses and free riders

As Goodhew [8] portrays it well, 'the issue of assessing individual performance during group or team work excites a lot of debate at meetings of academic engineers'. Inevitably, the question also arises among the teaching staff in this project course. The common dilemma in group assessment becomes manifest in the observation that groups quickly establish an informal 'work hierarchy': The 'cart horses' among the group members pull off the project while the free riders contribute little but finally

want to benefit from the assigned group mark. In the present project course, a group mark is assigned to every member of the group. A good cure against free rider behaviour is to include a separate oral submission in the form of a short presentation that allows to verify if every student is fully (or at least well) informed about what has been done in the group. But especially for larger classes, this also rises the effort considerably. Another way would be to moderate group marks based on observations of the peer groups [8]. However, other authors, like Kouliavtsev [9], object that 'students in groups systematically and substantially overstate their own contribution to a group project'.
After a long discussion whether to modify the group marks individually or not, a look on the obtained marks, made the teaching staff maintain the 'simple' marking model without a change. The reason for the decision is that the results show a 'self-adjusting' effect: For the best of each group (represented by the filled dots in Figure 7), there is a good positive correlation between the mark in the written examination and the project mark, see Figure 7, except for some 'outliers' that have been put in brackets. For those with the lowest mark within a group, there is almost a negative trend. But this effect is less pronounced.

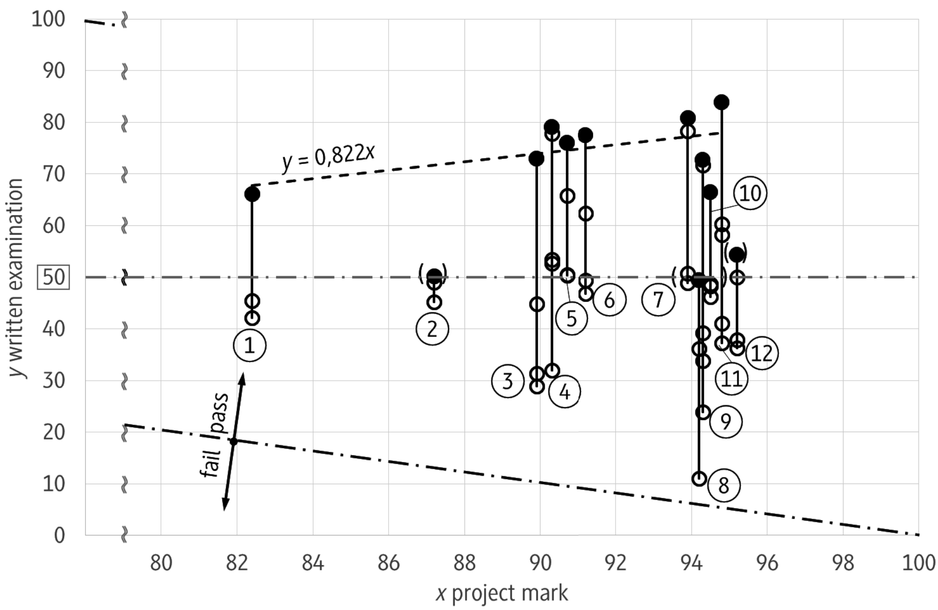

Figure 7. Correlation between the project grading and the written examination

5 ECONOMY OF TEACHING

Doubtlessly, it would totally overload a curriculum if design-build-test experiences were implemented in all modules of a study programme according to the 'watering-can principle'. Such a uniform implementation also would soon leave traces of weariness behind. Design-build-test experiences should rather occupy prominent spots in the curriculum. Capstone projects at the end of an academic programme offer perfect conditions for this type of deep learning experience, but take an enormous effort for both – learners and tutors.
Engineering Design projects – like this one – have a long tradition in Mechanical Engineering programmes. But especially when teaching large classes, teaching staff often gets 'immobilised' by the project assignment. Tutoring groups, manufacturing parts, marking reports – all this seems incompatible with large classes, cf. [10]. One of the contributions of this paper should be to focus on the 'economy of teaching'. The presented project course tries to reconcile large classrooms and individual experiences.
Owing to the exclusive use of supplied parts, the effort for the faculty's laboratory drops dramatically. The labour expended is reduced to the time needed for compiling the order lists and the actual

purchasing of the parts. The number of participants has been N=84 in the present project course, but can easily be scaled to larger populations.

The monetary costs for purchasing the parts in this project course amount to a maximum share of € 42.50 (VAT included) per student (working in groups of six to seven). As the groups did not fully exhaust their budget, every student needed € 31.13 on average in the present course. When being reused over an amortisation period of five years, the cordless power drills add approximately € 2.00 per student.

Compared to traditional chalk-and-talk teaching, project courses usually are a loss making-operation for the teaching staff in terms of the teaching load conceded. In this case, the three professors involved in the project receive eleven contact hours each and the same amount for preparation and wrap-up. In the first years when the project course has been set up, this was not even sufficient for reading and marking the reports. But investing more time for harmonising the classroom activities in a project plan led to less effort for assessing the results. For example, it did not take more than one hour for examining the assembly and testing videos– a 'frontloading' that definitely pays off!

6 OUTLOOK

In a project course like this, still more things can be optimised. In future, the authors will concentrate on the following measures:

- The student reception and perception need to be studied closer
- Team-forming meetings have to be introduced for permitting the group members to work more efficiently and with less friction from the beginning
- The qualitative feedback on the results of the groups given by the teaching staff should not allow to conclude 'sharply' on the project marking (before the written examination) in order to avoid the observed rebound effect on student performance

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DESIGNING FOR MULTISENSORIAL INTERACTIVE PRODUCT EXPERIENCES

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[2]Middle East Technical University, Turkey

ABSTRACT
This paper presents a methodology and case study of designing for multi sensorial interactive product experiences, within the context of postgraduate degree level Industrial Design education. Building on literature spanning product and interaction semantics, and multimodal product experiences, the paper establishes a stepped approach to integrate up to six different sensory modalities (sight, touch, presence, sound, smell, taste) into a user-product interaction scenario. A product design project (bedside alarm clock) is then introduced, for which nine postgraduate students were guided to design to a certain characterful interaction (e.g. charming, helpful, amusing etc.) using multiple sensory modalities. Each of the nine resulting product designs are scrutinised for the sensory modalities that are activated, making use of a storytelling (product usage scenario) analysis. The specific sensory attributes that were harnessed are compared across the product designs and the frequency of their implementation is charted. Conclusions are reached on (i) strategies that designers employ to reach intended multi sensorial UX for their products, and (ii) the effectiveness of the educational methodology adopted for encouraging student designers to think beyond the dominant visual domain of design.

Keywords: Senses, aesthetics, interaction, UX.

1 INTRODUCTION

User experience (UX) of products - sometimes referred to directly as ‘product experience’ - is a complex area of work falling within the remit of industrial design. Proper attention to UX requires designers to apply investigation, empathy and creativity to understand and shape the varied ways in which target users will preferably perceive and process their experiences of a new product. One of the significant factors in UX and contemporary 'design for interaction' (DfI) is multi-sensory engagement during product contact and interaction, for the purposes of affecting an interesting, coherent and positive overall experience [1]. However, relatively few case studies of how to design for multimodal product interaction exist, and even fewer studies offer insight into how such an important competence in industrial design may be nurtured in a tertiary education environment.

In the context of physical artefacts, user-product interactions are fundamental to shaping people’s experiences. The conceptualization of interactions at the front end of a project is a critical design step. DfI is a multifaceted and complex activity, requiring understanding of various characteristics of products, users and usage. Its basic premise is to design a product such that it leaves a trail of positive impressions on people through a series of definable interaction ‘events’.

Carefully thought-through interactions are seen as a powerful tool towards adding value to a product and positively influencing people’s experiences of that product [2]. Let us take for example two competing smart phones: one Apple, one Samsung. As with many A-B product comparisons in the current era of high-quality consumer goods, the functionality of both the Apple and Samsung products are similar, their retail prices are comparable, their brands are arguably equally prestigious (although invoke their own brand loyalties), their country of manufacture for the most part are likely to be the same, and both products are readily available in stores. Most of these factors are long established as central to people’s evaluation of product quality and influential on purchasing decisions [3,4]. However, with these factors becoming less differentiated, increasing importance is placed on product styling, materialization, DfI and semantics.

In this paper, we concentrate our efforts on an approach we term 'meaningful interaction', which seeks to make use of meaning concepts (usually expressed as adjectives or phrases) to steer intended interaction experiences in a characterful and multisensory direction. 'Meaningful interaction' is seen as an especially useful approach to DfI because it can be used to shape the qualitative experience of user-product interaction in a direct and comprehensible manner.

2 MEANINGFUL INTERACTION & AESTHETICS OF INTERACTION

Before we define 'meaningful interaction', we will first explain the phrase 'aesthetics of interaction' [5, 6]. In its contemporary setting, the term 'aesthetics' is used to catch multiple senses, in contrast to its traditional use tied only to visual product attributes. For example, the *purring sound of a dishwasher* or the *squashable grip of a toothbrush* are as much aesthetic experiences as the *shimmering finish on a digital camera* or the *sleek lines of a motorcar.* During interaction with a product, we may gain pleasure or displeasure from whichever of our six senses (sight, touch, presence, sound, smell, taste) are activated at any given time. Designers who seek to define such aesthetic experiences are said to be concerned with *how* an interaction is experienced, or with the *aesthetics of interaction.* They may be concerned with, for example, the *smoothness* of a gear change on a car, the *sharpness* of a knife as it effortlessly slices through fruit, the *comforting softness* of a sofa, or the *slickness of navigation* around a touchscreen operating system. 'Aesthetics of interaction' plays to our hedonic needs [7], since in its absence a product may still provide acceptable functionality albeit with far less pleasure and panache.

Meaningful interaction applies the principles of *product communication theory* and *aesthetics of interaction* into an actionable approach to DfI, centred on achieving a coherent interaction vision.

- Product communication theory: product designs where people are persuaded to interact in particular ways to achieve certain tasks, whilst being blocked from interactions that are considered detrimental [8, 9]. Krippendorff [10] provided the invaluable insight that: "... one always acts according to the meaning of whatever one faces...".
- Aesthetics of interaction: product designs for which the quality of user-product interaction is appreciated, found pleasurable, irresistible, etc.

In Desmet & Hekkert's affective framework of product experience [11], a triad of interrelated sub-experiences (comprising aesthetics, meanings and emotions) is used as an additive approach to defining overall experiences from user-product interactions. Their framework is relevant here because it is founded on sensory perception. They describe a progression through the sub-experiences, principally (though not exclusively) in an iterative manner, which importantly involves ever-increasing distance away from phenomena of products (e.g. sensorial information emanating from a product, aesthetic experience) towards phenomena of people (e.g. core affect, emotional experience). Benefiting from this perspective, 'meaningful interaction' essentially becomes the semantics of user-product interaction, or *interaction semantics* – where the subject of study is the meanings people attach to sensorial information experienced during interaction. In other words, we say that sensorial information (from an interaction) 'speaks to us' (semiotics, signs) and that we can 'tell something' from it (semantics, meanings).

3 METHODOLOGY

Designers are familiar with using adjectives or phrases to guide form creation in a particular direction, with a view to conveying intended messages through product form and expressive visual characteristics. The challenge in the work reported through this paper was to take the same thinking behind adjectival design approaches to form creation and apply it to meaningful multimodal interaction experiences. That is, to ask how to develop and apply an educational approach that focused not on, for example, generating an adventurous [looking] product but instead generating an adventurous multimodal interaction experience with a product? What kind of teaching and learning steps might be required? To do this, a seven-week research and design project was initiated as part of the elective course 'ID535 Design for Interaction', given to postgraduate industrial design students enrolled at the Department of Industrial Design, Middle East Technical University.

4 DESIGN FOR INTERACTION – A TEACHING & LEARNING FRAMEWORK

The purpose of ID535 is to provide students with an introduction to interaction design (IxD) and user experience design (UxD) within the specific context of materialized products. It therefore serves as a bridge between students' competencies gained through undergraduate industrial design training and more advanced studies in the field of product experience. Although the course is necessarily quite broad in its subject matter, a key principle is always that students must apply what they have learned through a half-semester long project.

In the most recent academic session, students used their course learnings to work on meaningful interactions for new bedside alarm clock concepts. This product was chosen because of its good potential for multimodal interaction, its relative simplicity in functionality and because its form need not be constrained by conventions. During the project, students defined an interaction vision, and then realized that vision through individual interaction episodes encountered along the path of interaction. To help navigate the possibilities of multimodal interaction, and to act as a source of idea inspiration, we constructed a taxonomy of sensorial information based on a literature review of sensorial terms (Figure 1). The taxonomy was inspired in part by the Kansei approach to product evaluation [12], in which a product is regarded as a transmitter of sensorial information across sensory modalities. Students were encouraged to consider how each of the sensory modalities could feature in their concept designs.

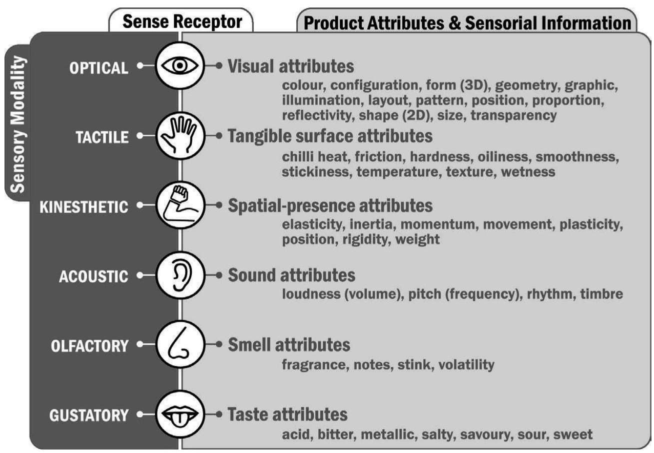


Figure 1. Taxonomy of sensorial information transmittable by physical artefacts

The project was managed across six stages, which in combination defined a method of ideation for meaningful interactions. Each stage is now described in detail.

Stage 1 – 'Visualized Connotations'. Students were individually assigned an adjective, which would later form the basis of a product interaction proposal (amongst: adaptive, amusing, calm, charming, cheerful, engaging, helpful, innovative, simple). The adjectives were chosen by the course tutors so as to stimulate considerable variety in interaction experience proposals. Students made a semantic exploration of their assigned adjective and prepared A3 posters to communicate the following.

i) By using <www.thesaurus.com> students decided on the particular 'sense' in which they would explore their adjective, and noted down synonyms for that sense.

ii) By using <www.dictionary.com> students chose a definition of their adjective and two preferred synonyms, which when combined would verbally communicate the essence of the connotations they sought to evoke.

iii) Students collated high-quality images of products and non-products that they considered to strongly embody their adjective and synonyms.

iv) From their 'product' images, students identified and justified which kinds of sensorial information they considered to convey their adjective and synonyms.

Stage 2 – 'Design Brief'. Students were made aware that the semantic explorations of the preceding stage would be taken forward in the context of meaningful interaction. The full design brief was distributed, explaining that the assigned adjectives would form the basis of product interaction ideation and development. Students were free to determine the target user for their product, based on an understanding of who may value an '…*adjective...*' interaction.

Stage 3 – 'Acting-Out Interactions'. This stage asked students to think deeply about their adjectives and synonyms and to work towards an interaction vision by building relevant usage scenarios and considering how an '…*adjective...*' interaction might be experienced in practice. Students physically acted-out their interaction and storyline ideas using supplied primitive forms.

Stage 4 – 'Product Critique'. As an in-class exercise, students were divided into groups to source Internet images and videos for 'bedside alarm clocks'. Each group created a map of product attributes that they found worthwhile for discussion, including features, interaction, forms, and technology.

Stage 5 – 'Product Development and 1-to-1 Critiques'. Students continued to develop their ideas by creating a storyboard (visual narrative) of potential interactions and product attributes.

Stage 6 – 'Final Presentation'. The completed projects were submitted as (i) a presentation board, (ii) a fact sheet, (iii) a lo-fi physical mock-up for live acting-out of interactions, and (iv) augmented reality content, projecting multimodal information onto presentation boards and/or mock-ups so that these static visuals and objects could be 'brought to life' [13].

5 ANALYSIS OF INTERACTION PROPOSALS

Figure 2 compiles the nine completed bedside alarm clock proposals, including their thumbnails, brief descriptions and analysis.

6 DISCUSSION & CONCLUSIONS

The portfolio of nine student product designs demonstrated very successfully how changes in the qualities of multimodal interaction dramatically affect product character and, hence, intended interaction experiences. The adoption of the 'meaningful interaction' approach was fruitful for stimulating creativity towards interaction visions that were distinct from convention and which potentially had commercial relevance (though this latter point was never an emphasis). Sensory activation across the student projects was distributed as follows: visual (all), acoustic (all), kinesthetic (8/9) and tactile (5/9). This is high and pleasing representation rate, showing that the educational approach was effective at encouraging student designers to think beyond the dominant visual domain of design. The potential of the approach to propose multi-sensorial UX for new products is therefore demonstrated, leading to speculation that the approach can now be adapted for use in commercial contexts. Industry-student collaborative projects would be a sensible starting point for such adaptation.

None of the projects included activation of smell or taste senses. In relation to product design, for technological and social reasons these are less easily deployed modalities and therefore less obviously considered by students in their own designs. These modalities are known to be under-represented in product interaction and feedback systems: manufactured products are rarely smelled (at least not as a step within an instrumental interaction cycle), and even more rarely tasted. That said, if the design task shifted to a different product sector where smell and taste were relevant or prominent, the 'meaningful interaction' approach could well yield good results across the full range of sensory modalities. Follow-up studies can be conducted to investigate this point.

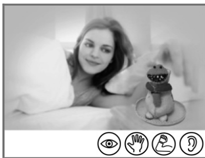
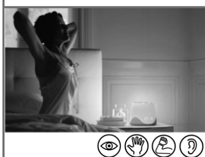
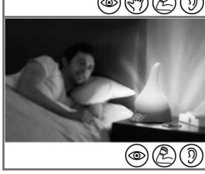
	**Adaptive Interaction**: serving or able to adapt; showing or contributing to adaptation. **'Mr.Quiet'** is a mechanical product 'creature' adaptive to users' sleep location and posture. Each day the user must set the alarm based on the amount of sleep to have, by pulling and extending the creature's tongue. Printed on the tongue is a scale of hours/minutes and a comment on whether the sleep duration is sufficient or not. The product is clipped to a nearby object (e.g. pillow, pyjama) and quietly makes its way back to the clip as the hours of sleep pass. It operates discretely by sounding its alarm and vibration in close proximity to the person sleeping.
	**Amusing Interaction**: pleasantly entertaining or diverting. The operation of **'Monolight'** uses magnetic resistance embedded in various locations around the anonymous looking cuboid body. The user sets the alarm time with a special magnetic stylus: as the magnetic resistance is felt more strongly, so the speed of the alarm adjustment increases. This gives a precision kinesthetic feel to the interaction, as well as a sense of amusement through its novelty. The amusement continues at alarm time, when a purring cat is sounded, gradually morphing into a wild cat if the alarm is not cancelled. To cancel the alarm, 'Monolight' must be turned on its head and into a recess, which requires effort to act against magnetic repulsion – surely waking up the user in the process.
	**Calm Interaction**: peaceful, quiet. **'Zen'** harnesses elements of nature for its interaction, and through each element a sense of calm is conveyed. The product gradually illuminates (mimicking sunrise) and emits initially quiet but increasingly loud sound as the alarm time approaches, to get the body prepared peacefully for waking up. Users define a soundscape by layering different 'nature' sounds (e.g. leaves, campfire, thunder) to wake up to. Each sound is represented tangibly as a pebble, making the placing and replacing of pebbles a ritualistic approach to alarm setting and cancelling.
	**Charming Interaction**: pleasing; delightful: a charming child. The icosahedron product form of **'Poly'** is purposefully captivating to generate curiosity and desire to pick it up and handle it. The product assumes a responsibility to wake up as well as tell when to go to bed (if desired) in an elegant, carefully composed manner. It has unobtrusive and clear functions shared with a smart phone (app) interface. In the morning, a random face of the icosahedron lights up, asking the user to pay special attention to locating it and shutting off the alarm by placing the illuminated face downward.
	**Cheerful Interaction**: promoting or inducing cheer, pleasantness, brightness. **'Daisy'** is animated, colourful and playful. It brings brightness at the time of waking up. The head of the clock – containing a light and ringer – leans over as it counts down to the alarm time, getting ever closer to the sleeping person's head and readying them for waking up. Unusually, one interacts directly with the 'clock hands' to set the alarm time; once the alarm time is reached, the mechanical hands literally 'clap' to sound the alarm.
	**Engaging Interaction**: winning; attractive; pleasing. **'DingDong'** tries to make the waking up process more engaging through a multi-sensory experience. Two minutes ahead of the alarm time, the product starts to warn the user with increasing auditory and visual alerts. When it is time to wake up, the display physically pops out and exposes the loudspeaker, resulting in an unsilenced and louder alarm tone. The display also exhibits a swinging motion to alert the user. Making an effort to place the display back to its base cancels the alarm.
	**Helpful Interaction:** giving or rendering aid or assistance like a caring, human-oriented and humanlike friend. **'IntelliWake'** is helpful in that it provides humanlike advice and greetings on its display, along with feedback about sufficiency of sleep durations based on the planned alarm time. Throughout the sleeping hours, the product displays how much sleep time is left. With the accompanying app, users can track their sleep durations over time and use the information to change sleeping habits for the better.
 	**Innovative Interaction**: using or showing new methods, ideas; tending to introduce something new for the first time. Innovative interaction is provided in **'GameClock'** through gamification of the waking up process and the form and functions provided on the product. The product is used as part of a social network, offering 'points' to members based on whether they can wake up early compared with friends. Points are deducted for snoozing and delaying the getting-up process. Points turn to real rewards once a total has been reached, dependent on the interests of the social network.
	**Simple Interaction**: clear, easy to understand, deal with, use, etc. In **'Sooth Up'**, dual functionality of a bedside lamp and alarm clock is provided. The product body is used as a tangible joystick controller offering simple movements: the x-axis mapped to alarm time up/down, and the y-axis mapped to lamp intensity up/down. To simulate the dawn, the product gently glows and its alarm becomes audibly louder as the alarm time approaches. Snoozing or cancelling is mapped to pushing the product body forwards or backwards.

Figure 2. Completed bedside alarm clocks with 'adaptive', 'amusing', 'calm', 'charming', 'cheerful', 'engaging', 'helpful', 'innovative', and 'simple' interaction.

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AN ENERGY CUBE PROJECT FOR TEACHING ENGINEERING DESIGN PROCESS

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ABSTRACT
This year, the College of Engineering and the Built Environment at our institute inaugurated a new Common First Year design project module that helps inform students in the selection of a specific engineering discipline. Each student, prior to selecting their bachelor's specialism, completes three group-based design projects: a bridge design project (to familiarise students with civil and structural engineering), a RoboSumo project (involving robotics, programming, electrical and electronics engineering), and an Energy Cube project (introducing fundamentals of mechanical, manufacturing and design, and building services engineering). This paper focuses on how the engineering design process was taught via the Energy Cube. It is geared toward third-level engineering educators who want to introduce a structured approach to design (that makes explicit the critical stages and activities of design). The paper explains how "The Informed Design Teaching and Learning Matrix" [1] was incorporated into the Energy Cube project and shows how the Matrix can serve as a valuable tool for design educators. Finally, it presents key observations made by tutors over four separate occasions running the project and the modifications made to improve the students' experience based on the analysis of class discussions, student performance evaluations, and more than 130 student surveys.

Keywords: Design process, problem-based learning, first-year engineering education.

1 INTRODUCTION

A newly implemented Engineering Design Projects module provides students with practical experience of the engineering disciplines that are available for focused study at our institute. It prepares students for the type of learning they will encounter in subsequent study and practice. Tutors on each of the three design projects took the initiative to meet throughout the year to discuss methods for teaching 'design'. They explored ways to both diversify and align the teaching methods they used.

In one of the three projects, entitled "The Energy Cube", students were introduced to design process theory via a short lecture that outlined key design stages, based on a typical stage-gate process used in industry. Students encountered a simple example to illustrate the process and completed an exercise to practice the initial stages of design. The teachers encouraged teams to adopt a similar approach in designing and building their Energy Cubes. Weekly activities and submittals were aligned to correspond with key stages of a design process so students could intrinsically experience it. In-class discussions were held around problematic areas, such as drafting a design specification document.

In this paper, Section 2 provides context and explains how the initial approach to teaching the design process was developed. Section 3 introduces the Energy Cube project and presents a week-by-week description of the module's content, with corresponding learning outcomes indicated. Section 4 describes student behavior. Section 5 notes how various recommendations from the design matrix [1] were integrated and explains how staff modified their approach to teaching design over time. Responses from a student survey highlighted the effect of these modifications (section 6). Concluding comments on the overall experience of teaching and learning a design process for entry-level engineering students are provided in section 7.

2 INCORPORTATING DESIGN PROCESS THEORY

One fundamental learning outcome of the three-project module is that students become familiar with the process of design. In it, they apply design tools to solve engineering problems. To provide basic structure for the design process, the lecturing team aligned the project's weekly activities to a typical stage-gate product design process (as outlined in Table 1), which the lead author had used in industry.

2.1 Providing a real-world experience—a typical design process in industry

A typical stage-gate design process, used in industry to spur innovative product design, consists of several fundamental stages. The first stage establishes the design objective (DO). It identifies clearly the customers' need and determines whether it is viable for the company to meet that need. Customer requirements are translated into engineering requirements, with specific targets/thresholds set and agreed within a multi-functional design team. If the project successfully passes through this decision 'gate' the 'Investigation-to-Lab' (IL) stage follows calling for more in-depth research and exploration to develop alternatives. On approval, with some concepts proving feasible, the Lab-to-Proto (LP) phase is then conducted to develop concepts further. In this phase, stringent testing is conducted on proto-typed functional products and their integrating parts.

The next stages are primarily troubleshooting and optimising the design to meet all targets and ensure readiness for high-volume manufacturing (called 'Week0'). On meeting this, subsequently the product is released to manufacturing (MR). A stabilisation phase starts when the product reaches the end-user and initial customer feedback is received regarding product performance. This process can be streamlined and adapted as necessary depending on project risk and complexity [4]. There are defined activities to be completed at each stage by each functional area, such as marketing, supply chain, manufacturing, and R&D. In the case of the Energy Cube project, attention was focused on R&D with identified outputs and activities expected during each 'stage' from this perspective. The latter part of a stage-gate design process (from 'Week0' onwards) was omitted due to the short time allotted for the project. The project was not focused on tailoring the design for high-volume manufacturing and release, instead it focused on creating a one-off energy efficient building design and model.

Table1. Correlation of Energy Cube Weekly goals and Design Project module Learning Outcomes

Week	*Weekly Output*	*Design Process 'Stage'*	*Design Module Targeted Learning Outcome*
1	Generate design specification documents	Design Objective - identify the problem clearly.	[b] Apply engineering concepts & design tools to solve engineering problems. [e] Recognise engineers' social roles, and relationships between technology and society.
2	Create a concept evaluation matrix, brainstorm ideas and select two preliminary concepts	'Investigation-to-Lab' - Research & explore to generate ideas	[c] Solve problems by following appropriate specifications and standards, as well as [b].
3	Make detailed construction drawings, submit thermal predictions and step-by-step construction plan	'Investigation-to-Lab' - Evaluate Concept(s)	[a] Operate effectively within design teams [f] Produce solutions to basic engineering problems using graphical methods, as well as [c].
4	Construct final model using the allocated materials	'Lab-to-Proto' - Build Prototype	This week re-emphasises [a] and [c] as described above.
5	Test performance of models and record results,	'Lab-to-Proto' - Test Solution	[d] Communicate results, verbally as well as graphically, in addition to [b] and [c].
6	Submit and present (as a team) a final report that includes recommendations for improvement and reflection on experience.	'Lab-to-Proto' - Reflect & Analyse, troubleshoot & improve (iteration)	[g] Distinguish the roles various fields of engineering play in the overall profession of engineering, as well as [a] and [d].

2.2 Simplifying the Design Process

An environmental scan of academic material [5, 6] and online resources [7, 8] was undertaken to see how the design process could be taught to third-level or even second-level (final-grade) students. This helped in tailoring the industry stage-gate process (outlined in Section 2.1) to this project. It simplified the model so students could achieve basic understanding and complete rudimentary design tasks. It was important not to overcomplicate the process given the broad spectrum of learning objectives and also to try to encourage students to enjoy the process and express creative flair without feeling constrained by stringent steps. It still aimed to expose students to tools real-world designers utilise.

2.3 Emphasising Important Aspects of the Design Process

It was verbally emphasised that an effective design process is both structured and iterative. Despite this, time was too constrained for iterative cycles. Students were asked to complete the vast majority of their work within six four-hour blocks. To echo the process driven nature of design, clear stages of the design process along with specified deliverables for each phase were introduced. Each team submitted and presented a final report that identified recommendations for future development and/or modification of their design. Although they did not conduct the actual refinement, the activity allowed them to troubleshoot and plan for future (hypothetical) iterations.
The role of the customer within an engineering design team was also emphasised. Customer-Centric Design, Human-Centered Design, and Quality-Function Deployment are all well established processes of ensuring design teams put the customer at the core of their design efforts. In this project, the client was incorporated via a 'story-based' brief, which described customer requirements. The percentage of marks allocated to various attributes reflected requirement prioritisation. Teaching staff positioned themselves as 'the customer'—clarifying requirements and answering questions.

2.4 Teaching the Design Process

As mentioned above, students were introduced to design process theory via a simplified stage-gate model. They practiced this theory by completing a design exercise and were encouraged to adopt a similar approach in designing their Energy Cubes. Short tutorials were provided to help students develop specific skills, such as drafting a design specification document and creating a weighted evaluation matrix. Specific weekly goals (depicted in Table 1) were provided, based on practical outputs that R&D teams deliver in real-world design projects. The weekly outputs helped the lecturing team implicitly emphasise a structured approach to design. A recap of design process was given in the fifth session when discussing the requirements for the final presentation and report. An information pack was distributed to help students prepare 'customer' presentations, re-enforcing the process.

3 ENERGY CUBE ASSIGNMENT

The original Energy Cube project was developed by a team of lecturers within building services engineering to help students learn about various aspects of heat loss in a building envelope. The project was revised by a multidisciplinary team of engineering lecturers—including one of the original developers—to emphasise additional learning requirements such as design process, design tools such as CAD, and effective communication and teamwork skills. The project was taught in four separate blocks of six weeks over two semesters. In all, about 160 students were asked to design and construct (using a limited amount of corrugated cardboard, clear plastic, and glue) a model of a building at a scale of 1:100. The building models were to admit as much daylight as possible while being energy efficient and aesthetically pleasing. The designs had to meet specific customer requirements such as a minimum volume and glazing area. Cost was factored into the project via a deduction of points in cases where additional material was used during construction.

3.1 Project Weekly Goals and Module Learning Outcomes

Student teams completed most of their work in six four hourly class-sessions. In each session, students are presented with theories on structured 'design process' as well as being given specific goals aligned with the module's learning outcomes. Table 1 indicates the relationship between the weekly outputs and each required learning outcome [a-g] alongside the relevant design process stage. Many broad outcomes must be achieved in a short time-period, and students have minimal prior-experience working in groups and with unfamiliar people. They must grasp core concepts quickly and develop basic design competencies. An over-riding expectation of the module is that students enjoy their initial taste of each discipline and are given the opportunity for exploration of many facets of the engineering world. In 'Energy Cube', grades/marks are allocated for each of the goals achieved by the teams. Self and peer assessment techniques are incorporated to enable individual marking of work conducted in groups. This is to facilitate reflection [2] and promote student engagement and performance [3].

4 OBSERVATIONS OF STUDENT BEHAVIOURS

To encourage students to develop their own ways to interpret the design process—and to enable them to explore and develop understanding of the design challenge—no additional information or templates were provided initially. Students were free to submit design specifications and evaluation tools formatted according to their own understanding of the project information. This prompted them to consider the value and content of these design tools and adapt them for their own design purposes.

It became evident very quickly (through a class discussion and in sharing the submitted design tools) that students did not understand the value of 'identifying and defining the problem'. They understood neither how to concisely extract the most important information from the design brief that informed the direction of their design, nor how to determine the quality of various schematic proposals in order to select the most appropriate direction. The first cohort of students jumped directly into generating ideas and selecting one, without fully understanding their design objectives and without creating criteria to support their selection process. Because of limited time, the first cohort on this project proceeded without completing this stage. On the presentation day, in discussing options generated, few teams mentioned using an evaluation matrix or tool to help in the down-selection process. However, the teams that did mention defining quality standards provided memorable graphics to describe their work, driving the point home to other teams. Notwithstanding this, student teams had regularly questioned lecturing staff in their efforts to comprehend customer requirements during design development (thereby reflecting customer focus). They also provided recommendations for improvement at the end (expressly stating their intentions for design iteration).

5 USING THE INFORMED DESIGN MATRIX TO ASSESS BEHAVIOURS

To enhance our lecturing team's efforts in (a) explaining effective design process to students and (b) modelling this type of behaviour for them, five of the 11 staff involved with the overall module volunteered to read and discuss the article titled "The Informed Design Teaching and Learning Matrix" [1]. The article's two-page matrix was analysed and our project assignments mapped to it. The group met several times exploring ways to embed activities with effective practices and explain design practices effectively. Figure 2 provides an overview of the matrix (where it compares a beginner's approach to an informed designers approach for various design strategies used in a design process) and it captures how applicable the Matrix is to this Energy Cube project.

Table 2. Summary of contrasting behaviours of beginning and informed designers distilled from [1] with applicability to Energy Cube project

Strategy	Begineer's Approach	Informed Approach	Energy Cube Applicability
Understanding the Challenge	Working to solve the problem	Working to frame the problem	Design Brief (9 pages) translated into concise design specification (1 page)
Building Knowledge	Skipping Research	Conducting Relevant Research	Research encouraged and facilitated
Generating Ideas	Trating ideas as scarce	Using ideas fluently	Idea from each group member encouraged
Representing Ideas	Drawing & modelling at surface-level	Drawing & modelling at surface-level deeply	Hand-sketches required as well as orthographic and surface development views
Weighing options & making decisions	Ignoring benefits & trade-offs	Balancing benefits & trade-offs	Evaluation matrix required prior to idea generation & populated matrix presented during customer presentation
Conducting Experiments	Vague tests & experiments	Valid tests & experiments	Dedicated tests discussed and performed to measure ability to meet design requirements
Trouble-shooting	Addressing glitches in an unfocused way	Addressubg glitches in a diagnostic way	Results recorded and analysed, findings presented during presentation week and in report
Revising & Iterating	Using a haphazard or linear approach	Using a managed & Iterative approach	Improvements required to be captured in presentation & report
Reflecting	Seldom reflecting on process	Continually reflecting	Reflection on project captured in report, presentation and student survey.

5.1 The Matrix influencing modifications to Energy Cube project

With regards to the Energy Cube, lecturers found it reassuring that the Matrix correlated well with prior industry experience—in sync with stage-gate product design methods. It mirrored the structure already created for the Energy Cube project (Figure 1). Interestingly, each of the matrix's design and corresponding teaching strategies aligned somewhat with required Energy Cube outputs (Figure 2).

This made clear the relevance of this Matrix to the Energy Cube project. In response to these findings, simple templates for the design specification and evaluation matrix were created so that students could populate them with relevant information rather than creating them from scratch. The templates helped reiterate and reinforce effective design practices. Marking was re-allocated to reward teams that developed, for instance, an evaluation matrix to support their selection process. These tools were discussed briefly and provided in soft and hard copy, minimising formal lecturing time (aligning with student recommendations in end-of-project surveys). In keeping with the Informed Design Matrix, our emphasis on representing ideas in multiple ways helped re-enforce the need for the design teams to create scaled prototypes, detailed hand sketches, and 3D drawings of their ideas—encouraging teams to analyse their concepts before determining which proposals to build.

5.2 Using the Matrix to Guide Design Process

Overall, the Matrix's identification of specific patterns of behaviour (and descriptions of how behaviours differ between novice and informed designers) provided excellent guidance on teaching design to beginners and in trying to understand the observations outlined in Section 4. It's easy to forget, after years of professional practice, the tendency of novice designers to act prematurely when facing a new challenge. The practice of conducting investigations and research to learn about the problem (prior to brainstorming for solutions) is not necessarily an obvious step for individuals with minimum exposure to design. As a result, the staff facilitated team-based discussions acknowledging this tendency and helping students address their discomfort in having to define a specific problem from a multitude of information.

The Matrix proposed a range of teaching strategies enhancing our teaching team's ability to explain 'design strategy' in different ways, thereby helping students understand 'design' more clearly. For example, students were encouraged to broaden their perspectives through: brainstorming to look at process of divergent thinking; reverse engineering; writing a product history; and reading case studies.

The need to achieve a level of comfort with ambiguity—as described in the Matrix—resonated. It is recognised as one of the most challenging aspects of engineering design acknowledging that engineering does not lie in well-structured problems with clear definitions. Creativity and innovation can sometimes be stilted as a consequence of rushing to solutions immediately. Again this was acknowledged by staff through discussions. Students were reassured that uncertainty is natural and to be embraced at this stage in a design process, encouraging unconstrained creativity.

6 FEEDBACK FROM THE STUDENTS

On the last day of each six-week session, students were surveyed about the level of value and enjoyment they obtained in each session of the project (team-building, design process, designing the cube, the physical build, testing, and presenting their final designs). In total, 133 students responded to the survey with an overall response rate of 80%. Although just 10% of respondents listed the *design process* tutorial session as the most valuable, a full 20% indicated that *designing* the Energy Cube was the most valuable activity they encountered. When compared to the other sessions, the design process session was indicated as the least enjoyable session by 15% of respondents. To us, this suggests that while students may not necessarily appreciate—or enjoy—having to learn about design in *theory*, they appreciate being able *apply* these methods in practice. Their ratings may also indicate they do not yet see the role of theory in practice. After modifications were made to how the design process was taught, the percentage of students selecting design process as 'most valuable session' increased from 9% to 12%—yet the percentage of students voting it 'least valuable session' also increased from 13% to 24%. Happily, the percentage of students listing the design session as their *favourite* increased to 3% and as least *favourite* decreased from 21% to 13%.

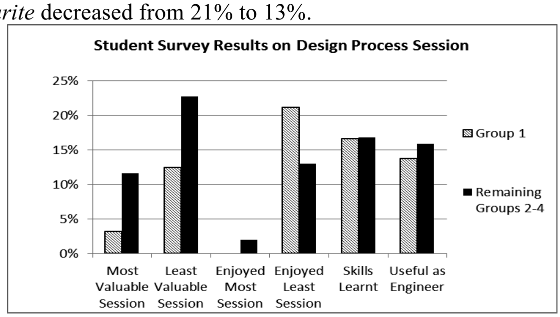

Figure 1. A comparison of Students' response of the value and enjoyment they obtained during the design process session before (Group 1) and after (Groups 2-4) teaching modifications

17% percent of students felt they learnt the skill of designing via a structured process with 15% feeling it was the most useful skill to have as an engineer. This makes sense considering the complexity of learning to design. We also note that the other skills learnt—problem solving, the ability to draw and to participate effectively on a team—may be required in more engineering settings than design and may have been considered in the 15% rating students allocated to 'design skill'. This low level of capacity students specified could possibly indicate that they did not see the connection between the structured design approach we provided and the process they followed. They may not correlate theory with the process they had just completed and learnt. There were improvements in the perception of the design process session among the students between the first cohort (weeks 1-6) and the remaining groups, as illustrated in Figure 3. After we modified the way we described 'design process', the remaining student cohorts ranked it as more valuable and marginally more enjoyable. They also indicated a slight increase in its usefulness as a skill for an engineer. Notwithstanding this, students still seem to struggle to see the value of the theory session even with the modifications made. On-going tutor-led discussions regarding how the design tools and design process theory fit into the project reflected some positive change over time, however.

7 CONCLUSION

Overall, the Informed Design Matrix [1] was found to be an invaluable tool in teaching design process. It helped lecturing staff understand what students might be thinking or feeling during each stage of the design project. It provided specific advice to teachers at each design phase. We believe it provides a solid framework and a clearly defined 'end goal' for new designers to work towards.

With regard to the Energy Cube, the very limited time allotted curtails the level of questioning, exploration, research, and depth each team could afford. Our lecturing team found a roundabout way to encourage reflection, troubleshooting, and iteration by using the students' final report as a time for them to identify areas for improvement and reflect on design process. At this phase, we asked students to comment on the results they had found in testing their models. We asked them to recommend ways their designs could improve—these are aspects of iteration in design. Although there were mixed reviews regarding perceived value of the design session in the overall design project, and more work needs to be done to help students understand the value and enjoyment of design. In addition lecturers delivering the original building services energy cube module remarked on the much greater variation in designs among this group compared to their groups which tended to be, literally, cubes.

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SUPPORTING VALIDATION ACTIVITIES AND SELF-REFLECTION PROCESSES IN INTERDISCIPLINARY DESIGN TEAMS

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ABSTRACT
In order to fulfil customer demands with today's complex mechatronic products, verification and validation activities are crucial elements within a product development process [1]. These activities comprise the preparation of prototypes, the selection of suitable environmental models, the testing procedure itself, and the acquisition and analysis of the test results. These tests can be classified and distinguished by various factors [2]: (1) use case affinity, (2) system levels, (3) validation purposes and (4) test compositions. The characteristics of all these factors have to match to the actual level of knowledge. To define the suitable test case for a specific validation objective needs a lot of experience [3] and may cause iterations or rework [4].
A new interdisciplinary mechatronic course is established this year at the Karlsruhe Institute of Technology (KIT). Within this course, 40 undergraduate students attend lectures, exercises and perform an accompanying development project. In this development project, the students develop concepts, build prototypes and conduct validation and optimization activities. A web-based tool supports the students in planning and documenting of the test restrictions, the execution, interpretation and reflection. The tool bases on theoretical findings from analyzing different validation activities.
It guides the students through a set of questions and answering options. These questions refer to a general description of the test setup (for documentation), to a specific classification of the test and to interpretation of the results. The specific classification gears towards the above-mentioned four distinguishing factors (1) to (4). The interpretation focuses possible biasing effects on the results (their reliability) and the consideration of existing uncertainties and resulting possible deviations.

Keywords: Validation and certification, x-in-the-loop, project-based learning, test interpretation, team reflection.

1 INTRODUCTION

The innovative capacity of highly developed systems and products are a key factor for Europe's leading economic position. To fulfil customer demands with today's complex mechatronic products, verification and validation activities are crucial elements within a product development process. The demands on today's designers and engineers are rising and it is getting harder for an individual to keep an overview on the whole product development. Additional to that product validation process as well as systems getting more and more complex. For success in today's development projects, engineers have to apply knowledge of the fields of mechanics, electronics and information technologies – called mechatronic.[1] The understanding of the term mechatronics in this paper is as follows:

> *Mechatronics denotes an interdisciplinary development methodology that solves predominantly mechanically oriented tasks by synergetic, spatial and functional integration of mechanical, electrical and information processing subsystems.*

It is expected from mechatronics engineers to have a broad general knowledge and detailed knowledge in a field of specialization. This knowledge should be applied together with methodological expertise to solve complex problems by finding innovative cross-disciplinary solutions. New processes, systems and product should be designed by using mechatronic synergy potentials. The survey ‘Faszination Konstruktion’ (engl. fascination engineering design) [1] points out the need for so called system engineers that possess knowledge in the fields of mechanical, electrical and information engineering, manufacturing and assembly techniques, project management and creativity techniques. As published by Matthiesen et al. [3] a curriculum for mechatronic engineers has been developed at the KIT. As described above and in Matthiesen [2] the day to day business of mechatronic engineers and the development of industrial mechatronic systems are influenced as followed:

(1) Mechatronic system are developed in **interdisciplinary teams**
(2) Usually development teams are not located in the same office – they are **locally separated**
(3) For develop innovative products a **structured engineering process** is needed
(4) System development requires **development**, **manufacturing** and **testing**
(5) Mechatronic system development needs **continuous validation and testing** with prototypes fitting to changing knowledge base
(6) Mechatronic systems will be developed **under industrial working** conditions
(7) Development of mechatronic systems is not straight forward. Provoke early and cheap **iterations** and reflecting them are very important.
(8) For mechatronic system development projects an **interdisciplinary system modelling** is required
(9) Successful systems are **winning products** on a specific market

2 COOPERATION-FOCUSED EDUCATION

At the Karlsruhe Institute of Technology (KIT) an educational concept for project-based learning, focusing the cooperation in mechatronic engineering teams is developed. The concept was tested in a pilot study and was fully implemented in a mechatronics course in the winter term 2014/2015. It is a project-based teaching approach especially for mechatronic engineering courses, focusing the interdisciplinary cooperation and the development of profession qualifying skills. This concept is designed and carried out from two different departments – the department of mechanical engineering and the department of electrical engineering. It is part of the Karlsruhe Education Model for Product Development (KaLeP) [4], which emphasizes the particular importance of project work in a realistic environment to enable engineering key competencies. By experiencing in specifically created learning situations, students gain competence in solving real complex mechatronic problems.

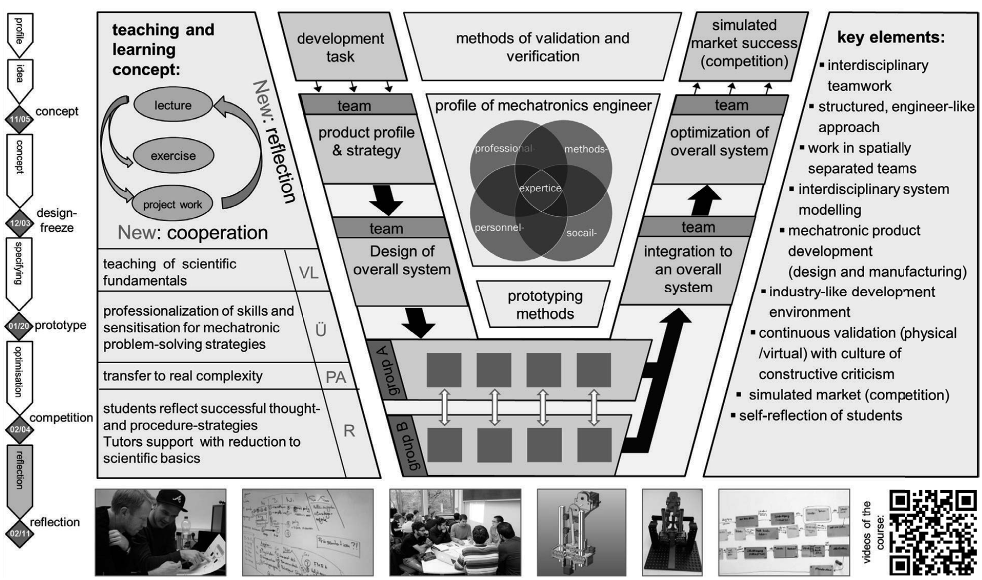

Figure 1. Framework of the course development of mechatronic systems and products

The course *‘development of mechatronic systems and products’* consists out of lecture hall sessions with integrated exercise phase’s und a development project. The deep expertise from other bachelor courses will be connected and supplemented by tangible and applicable product development competencies (development, production and validation). In order to implement the elements of development of industrial mechatronic systems and to let the students experience product development, a development project is imperative needed. As shown in Figure 1 the project is divided in the stages profile, idea, concept, detailing, optimization and reflection. With this guided stage gate process most parts of the industrial product development process is covered – from strategy over design and manufacturing until the market introduction and measuring the success in the market (time-to-money). One of the key elements of this concept is cooperation – for the final succeeding – two groups (5 persons each with individual responsibilities) have to work together very close as one team. Thus, each group is responsible for its own subsystem, but to achieve the shared goal, the team has to continuously discuss, negotiate and decide about the requirements and constraints for the overall system resulting from their jointly pursued strategy. To simulate more realistic industrial conditions the groups don't work next to each other – they are located in two different working areas on the campus. The team has to develop, manufacture, validate and optimize a mechatronic system to solve the development task. The systems of all teams have to perform on a simulated market against each other. Milestone meetings are carried out to check the project progress. According to the stages the students have to present previously defined development results (strategy, constructions and reasoned decisions) which will be discussed together with the supervisors. Indeed the students have a project plan, best practices and recommendations for each stage, but it's a long and winding road of development, iterations, verification and validation. However, each product development is individual [4] and the students are faced with the decision: In which cases either physical prototypes or virtual models are suitable to support our product development and to demonstrate the functional performance? When does it make sense to test sub-functions or the overall system in the development process? The next chapter gives a closer look at the aspects of validation and its support by the effective use of physical or virtual prototypes. Many project-based teaching approaches doing finally any kind of competition. In this course the competition is not the end of the course. There is a final lecture including a student reflection phase. In this lecture the students reflect the experienced development project based on competition and present and discuss their learnings with the advisor.

3 VALIDATION ACTIVITIES IN PRODUCT DEVELOPMENT PROCESSES

Accompanying validation activities along the product development process are crucial for product engineering. Such tests vary in their specific setup. Albers et al. present four criteria to distinguish different validation setups [6]:

System level: Different tests vary in their system level of the System under Development (SuD). The system level reaches from a single Working Surface Pair (WSP; low system level) to the complete technical system (high system level). Even on the software or mechatronic area, a single software snippet or the overall software can be tested.

Composition: Validation activities vary concerning their proportion of virtual and physical models. The criterion composition distinguishes between virtual tests (i.e. simulations), physical tests and hybrids between virtual and physical tests.

Use case affinity: The use of realistic or abstract test runs and the selection of detailed or reduced models lead to input values of the SuD that either equal or differ from the real use case. Nevertheless, this criterion does not evaluate the quality of the test output. The SuDs input values are described from 'equals the real use case' to 'far from the real use case'.

Validation purpose: The purpose of the validation activities is another criterion to distinguish different tests. On the one hand, a test can examine the fulfilment of the overall customer demand. On the other hand, a test can check the achievement of a quantified technical requirement (like weight or speed). Between these extremes there are the examinations of the desired sub-function and the desired overall function. The four characteristic criteria are transferred into a model, which can be used for test-analysis; test-definition and test-planning (see Figure 3). The test characterization model was provided in the form of an online survey in which the students could document their validation activities. Therein the students were asked for describing the test and rating the four characterization criteria. Furthermore, they could document the results and the interpretation of the same. By filling out the survey, the students had to think about the purpose of their tests, if the test could generally lead to the intended finding and how to interpret the results. From the research's point of view the online survey was a very performant tool to analyze the different validation strategies of different teams, which are presented in the next chapter.

4 VALIDATION STRATEGIES OF MECHATRONIC STUDENT TEAMS

As already described, the basics in the field of development processes, interdisciplinary modelling approaches, importance of iterations to knowledge gaining, different types of testing and the basics of model-based design were taught in this course. The students have incorporated this knowledge directly into the processing of the development task and each team has chosen for himself, at which point sub-functions or the entire system have been validated with prototypes or virtual models. The development project was scientifically supervised and the realized development stages were analyzed. The developed systems are shown in Figure 2. The following procedures and strategies have emerged here:

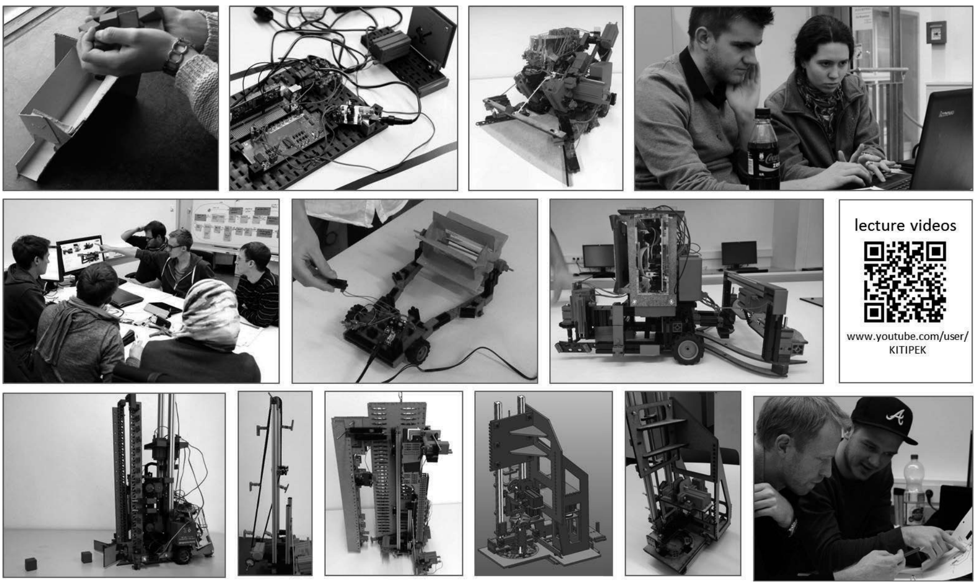

Figure 2. Observation of mechatronic teams during the development project

An Iterative Adaption: This approach is characterized by the fact that there is a large number of iterations, a continuous adaptation of the development depending on a changing knowledge base and a sequential development. The development steps were little thought ahead and the interfaces between the teams were only moderately specified in detail. Virtual models were used only moderately. Pros and Cons: low development risk, as a functional system was always available. However, the development progress was slow and a high use of resources was necessary.

B Focus on the development of subsystems: This strategy is characterized by a detailed analysis of all components. The development of the subsystems was parallel and physical validation of the subsystems was carried out in great detail. The integration of the overall system and its validation (test on overall system level) took place at an advanced stage. Pros and Cons: Each subsystem was developed focused. The late integration is a risk in a sense that the sub-systems do not work together properly and large iterations occur.

C Validation on overall system level: This strategy is characterized by a parallel development of the subsystems and early integration into the overall system. Validation is performed mainly physically on overall system level. Pros and Cons: All subsystems were tested very early in the physical overall system concerning the fulfilment of functions. However, the sub-systems' level of maturity was partly not high enough, so that some sub-systems had to be disassembled again to get optimized.

D Detailed virtual modelling: In this strategy, a top-down approach with integrated SysML modelling can be seen clearly with a distinct definition of the interfaces between the teams, clear responsibilities within the team, a sophisticated CAD design and the advanced utilization of virtual models. The physical validation of sub- functions took place very late. Pros and Cons: All subsystems were tested virtually and a very fast development progress along a preconceived process could be observed. However, only few functional prototypes have been developed, which is why some critical points were identified very late.

Generally it can be observed, that some of the validation characteristics change over the development phases. Especially considering the system level there is a mayor change from first project phase to the second. In the first phase, the students mainly validate on the level of discipline-specific sub-systems to validate single requirements or sub-functions. On the contrary, in the second phase the level changes to cross-disciplinary sub-systems (see Figure 3). This is comprehensible since the later in the project the more integration of single components into more complex sub-systems has been conducted and has to be validated compare [5].

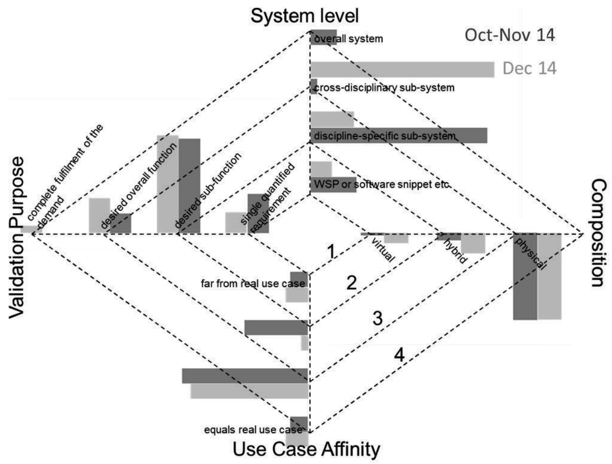

Figure 3. Test characterization model with results from the student project divided into two development phases (first phase – dark grey, second phase – light grey)

5 STUDENT SELF-REFLECTION

Many project-based teaching approaches are doing some kind of competition at the end of the semester. In this case the competition is not the end of the course. However, the goal of this teaching approach isn't the development of mechatronic systems and the best rank in the competition – it is the best possible preparation of the students for their future job. Therefore, one week after the competition a final lecture including a student reflection [8] phase takes place. In this lecture the students reflect on the experienced development project based on the competition results. They present and discuss their learnings with the advisor. The tutors will support the students during their self-reflection and transfer the experiences on general issues and link them to the scientific basics in the lectures. Thus, the control loop of lectures, exercises and development project will be closed and the students can transfer the experience out of this course as good as possible on future challenges. The self-reflection shouldn't be an individual reflection furthermore a reflection concerning the complete project team behaviour. The procedure for doing that is divided in three steps: (I) intuitive collecting of experiences & learnings and searching for specific examples in the development project. (II) Introducing and concentrating of these experiences & learning in the group. (III) Negotiating of experiences & learnings in the team (2 groups) and development of better solutions in future projects. With the goal of a wider variety of experiences & learnings the reflection has to be done in 4 different clusters:

- **Engineering topics**: design, manufacturing, controlling and programming and systemic mechatronic contents.
- **Process topics**: process flow, project planning, strategy, validation iterations
- **Team work and social topics**
- **2 open topics**

Especially in the field of development processes and in particular concerning validation activities the students gained a lot of experience. Particularly the documentation and self-reflection pushed the students to analyze their development and testing process systematically. They recognized testing plays a central role in the development of a reliable product [7].This can be seen e.g. in the following student's statements: *'Our team becomes aware of the importance of prototypes, validation and iteration. Next time we will validate our system earlier and much more target-oriented.' 'We were on the wrong track: We developed and validated only one component in detail and lost the overview of the whole project.*

6 SUMMARY

By solving a real complicated development task in a realistic development environment, the students gain experience and are getting well prepared for future challenges. By pushing those towards systematic validation activities the teams learned to think about the purpose of a certain test and how to interpret the results. By analyzing the validation strategies the following aspects can be observed:

- Validation of the sub-systems took a lot of time, whilst the teams lost sight of validating the function of the overall system.
- Pure virtual validation does not result in sufficient certainty about the functional fulfilment.
- A very late validation on the overall system level brings the risk of late major problems and iterations.

7 OUTLOOK

Besides supporting the students with the test characterization model, the usage within the project provides a comprehensive documentation of manifold validation activities. Specific validation characteristics lead to more effective validation activities in certain development phases. The goal of future research work is to define effective test characterizations for different development phases. The knowledge about such dependencies can support upcoming student generations in their project work. Additionally these results can possibly be transferred to future industrial development processes.

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SURGICAL APPLIANCE DESIGN THROUGH STUDENT CO-CREATION AT PAL-WEEK

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ABSTRACT
PAL-Week has been developed out of the desire to transition 1st year UG Design Engineering student's learning responsibility and frame the expectation of their University experience through engagement in the first academic week of the year. A novel blend of Peer Assisted Learning (PAL) and Project Based Learning (PBL) techniques provides a rapid learning process with 1st year expectations formed directly through working with their 2nd year colleagues.
For their brief, mixed groups of 1st and 2nd year students were asked to design a left radial arm support to assist Interventional Cardiologists from the Cardiac Intervention Unit (CIU) at Royal Bournemouth Hospital (RBH) when conducting Transradial Coronary Angioplasty. The surgical procedure is generally conducted from the right side of the operating table and where the catheter is inserted through the right arm this falls naturally for the procedure.
Students researched, analysed and designed viable solutions for the radial arm support and presented solutions at key intervals to staff and peers. The final presentation was submitted as a narrated YouTube video and scaled prototype with all group members questioned.
Success can be framed from four perspectives: Firstly, student expectation has been set at the outset of their academic careers. Second, students understand their responsibilities within the transition from taught lessons to student managed learning. Third, students have been introduced to new technology and appropriate methodologies. Forth, the practical outcomes, from the work they have done, are currently informing the development of a working prototype device in partnership with the CIU.

Keywords: PAL, PBL, design.

1 INTRODUCTION

In common with many institutions, there has been a drive to enhance the student experience within our University Faculties through the integration of Research, Professional Practice and Education under a formal theme. For our University this is known as Fusion and is fundamental to the strategic plan [1] with funding streams available to encourage projects that embody this concept [2]. Funding typically support three streams: Student co-creation, staff mobility & networking and study leave. For this project co-creation funding provided equipment and materials in support of a PAL-Week design project in conjunction with the Cardiac Intervention Unit at the Royal Bournemouth Hospital.

1.1 PAL

A recent Higher Education Academy report [3] examined 150 separate PAL schemes from 55 HE institutions. Despite the wide range of PAL-type programmes discussed the underlying guidelines, principles and benefits remain the same and can be distilled to: Support student learning; cross-year student support; enhanced University experience; participative and collaborative; addressing what and how students learn; insight into lecturers' expectations; of benefit to all students. Ody [4] in [3] supplements with the promotion of academic and social communities, while Hilsdon [5] identifies the community of practice providing *"greater emphasis on legitimate participation and critique"*.

1.2 PAL-Week

PAL-Week was originally devised to bridge the gap in educational engagement with Sustainable Development relative to that found in some of the more pragmatic business sectors [6]. The underlying structure was informed through international best practice identified at Delft University [7] including their "Boat-Week" activity [8], Cambridge University [9] and Manchester University [10] as well as our own programmes. The key objective was to promote students understanding of Sustainable Development and the impact upon the work they do as Designers and Engineers [11-13]. Despite the focus upon Sustainable Development, it is the learning methodology that emerged from these programmes that defines PAL-Week, rather than the subject matter delivered.

1.3 PAL-Week Method

PAL-Week has developed into a means to transition 1st year UG Design Engineering student's learning responsibility and frame expectations of their University experience through project engagement in the first academic week of the year. A novel blend of Peer Assisted Learning (PAL) and Project Based Learning (PBL) techniques provides a rapid learning process; here the students' transition from dependency of taught to the personal responsibility of self-directed learning is the key to success. Students receive no formal teaching or didactic elements during PAL-Week, instead they receive guidance through their presentations' feedback and daily briefings. Students are, however, introduced to the design process (Figure 1) described in BS8887 [14] and BS7000 [15].

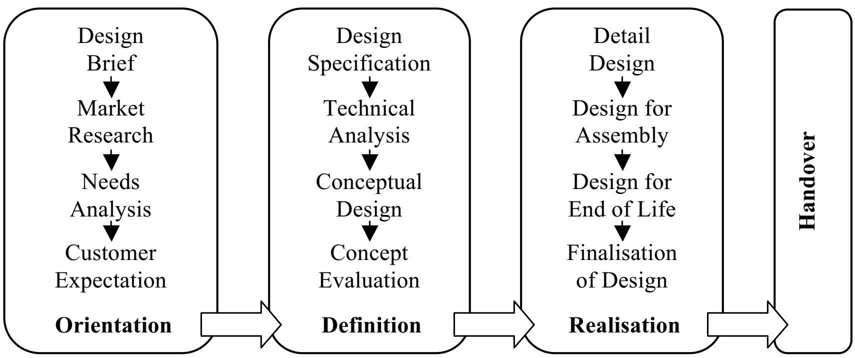

Figure 1. The Design Process, adapted from [14]

For some, this is their first time presenting to a critical audience and provides a direct method for students to measure the importance of their contribution. All students are expected to contribute to the group and for 1st years, it provides the opportunity to integrate and adapt to university learning during the first academic week rather than over the course of the first academic year. For 2nd year students, it provides an opportunity to mentor their peers in the use of facilities, design process, work ethic and university expectation. For the Academic, PAL-Week provides an opportunity to trial new techniques, promote unfamiliar topics and gain valuable insight into Student understanding of academic endeavour.

1.4 PAL-Week Objectives

PAL-Week objectives can be categorised in three distinct ways:

1. Project Objectives: Practical outputs generated by the students and represent the project goal.
2. Student Objectives: These are directly related to the guidelines in 1.1 and can be sub-divided: *Student Learning*: develop their broader knowledge of the design process applied to a real problem; *Student Experience*: develop working relationships with their peers and an understanding of how to manage the learning process; *Student Expectation*: working with their 2nd year colleagues, students understand the work ethic and academic endeavour that is expected of them at University.
3. Academic Objectives: These outcomes represent the goals of the academic team. They include evaluation of new learning methods and the application of untried technologies.

2 PAL-WEEK PROJECT

For their brief, mixed groups of 1st and 2nd year Design Engineering undergraduate students were asked to design a left radial arm support to assist Interventional Cardiologists from the Cardiac Intervention Unit (CIU) at Royal Bournemouth Hospital (RBH). When conducting Transradial

Coronary Angiography (CA) and Percutaneous Coronary Intervention (PCI) procedure it is generally conducted from the right side of the patient and, where the catheter is inserted through the right radial artery (RRA), this falls naturally for the procedure. However, clinical factors can occlude the RRA such that the left radial artery (LRA) is preferred although the layout of the catheter laboratory and monitoring systems dictates that the LRA is accessed from the right side of the patient (Figure 2). The LRA procedure is hindered by difficulty in securing the arm in place, across the body, for insertion and manipulation of catheter, stents and ancillary devices. When the Cardiologist and surgical team work across the patient to perform the left arm procedure they become susceptible to fatigue and injury to the lower back, knees and calf muscles. Fatigue is greatly compounded by wearing lead lined protective tunics and neck bands to shield against harmful emissions of ionising radiation which is necessary to visualise the coronary arteries and perform angioplasty. Left radial artery access is also more uncomfortable for the patient with the lack of arm support currently available.

Figure 2. Catheter Lab, Bournemouth CIU [16]

2.1 Wider Objectives

For the practical development of a viable technical solution the students needed to expand their repertoire of skills and technical understanding through the practical application of ergonomics. To achieve this, students were asked to use 3D laser scanning devices to capture data of shape and form from each other's bodies. This required students manipulating each other in a prone position to simulate the patient's position prior to data capture. The groups were also asked to create a physical scaled model using rapid prototyping techniques and present using Youtube video rather than the customary Powerpoint to deliver their findings at key stages.

None of the students had used video before as a presentation medium and the use of laser scanners and rapid prototyping was also new. In the case of Video presentation, no workflow method or training was provided. In the case of rapid prototyping, the Makebot Replicator machines were new, untried and there was no established workflow in place. For the 3D Laser Scanners, three Cubify Sense 3D scanners were purchased specifically to support the project and, again, were untested prior to PAL-Week and no workflow established.

2.2 Ethical considerations

For Fusion Funded projects it usual to conduct an ethical review of the project; the involvement of students and the nature of data collection led to a review by the University Ethics Panel where the project was approved. A participant information sheet (PIS) and informed consent were required prior to any photographic or electronic data collection.

3 DELIVERY

PAL-Week was delivered over the course of the first formal teaching week of the academic year with 1st and 2nd year Design Engineering students distributed into mixed groups comprising 7-8 members. The programme was divided into four parts of defined duration with their own distinct objectives; each part began with reflection upon the previous outcomes, refocusing of specific objectives and concluded with student presentation of findings.

3.1 Objectives

For the first part of the programme students were provided with a short overview and asked to formulate a development plan for oral presentation to their peers within two hours.

For the second part they were asked to refine their work plan develop a technical solution delivering their oral presentation over a four minute Youtube video and specifically asked to consider:

- Function; a functional description of the technology what the product will do and how it does it. The operational performance quantified and the technology deployed should be described.
- Material; identify materials used in the product and the processes used for production.
- Anthropometric variation; variations of human form; provided with hand held 3D laser scanners.

For the third part they were asked to consider material compatibility, technology transfer and prototyping. Presenting the following day in the same format as before and specifically to consider:

- How similar solutions are used in other industries or products.
- Whether prototypes should be for the full product or key elements and relevant scale.

For the fourth part of the programme, students were asked to optimise the product's design for ease of use, decontamination, service and disposal. They were also provided access to Rapid Prototyping machines and brief instruction on lay-up criteria. Each group was provided a consultation to discuss the project with members of the Academic team. Final presentations were delivered as video with audio narration and questions from the Academic team. Assessment of student work was based upon the final presentation & questions with weighting given to student contribution within each group.

4 OUTCOMES

Student output can be evaluated through the review and quantification of content from their final Youtube Presentations. Each video was previewed to formulate a matrix of both common and relevant content before quantifying to key characteristics (Table 1). Formal academic assessment of the work was toward the satisfaction of the bulleted objectives above and is not the subject of this paper.

Table 1. Output matrix from Final Student Presentations

	Output / Group	1	2	3	4	5	6	7
Orientation	Expert Consultation				Yes		Yes	
	Market Data	Yes	Yes		Yes			
	Competitive Products							Yes
	Anthropogenic/metric data	Yes	Yes	Yes	Yes		Yes	
	Patient Orientation	Yes	Yes	Yes		Yes		
	Scan Capture	Yes			Yes	Yes		Yes
	Scan Examples	Yes						
Definition	Materials	Yes	Yes		Yes	Yes		Yes
	Analogy	Yes						Yes
	Concept Sketches	Yes	Yes		Yes	Yes		Yes
	CAD Models	Yes	Yes	Yes		Yes	Yes	Yes
	Other Models				Foam	Yes		
	Full Design		Yes		Yes	Yes		
	Context					Yes		
Realisation	Makerbot layup/output	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Right / Left hand mounting		LHS	LHS	LHS	LHS	LHS	LHS
	Floor or Table mounting	Table	Table		Table	Floor		
	Articulation	Yes	Yes		Yes			Yes
	Telescopic Adjustment	Yes	Yes		Yes			Yes
	Whole Arm or Forearm		Whole	Whole	Whole	Fore	Whole	Whole
	Wrist Orientation	Yes	Yes					Yes
	Length of Video	04:10	3:35	2:48	3:18	3:34	3:54	3:23

4.1 Project Outcomes

For their presentations, students described their work within the three key stages of the design process. Most groups provided a good description of the inputs to the orientation phase, in other words how they gathered their research data, but failed to distil this to a product design specification or statement of need. Although all student groups used the 3D laser scanners and most showed the process only one group used the output of this tool within their final presentation (Figure 3).

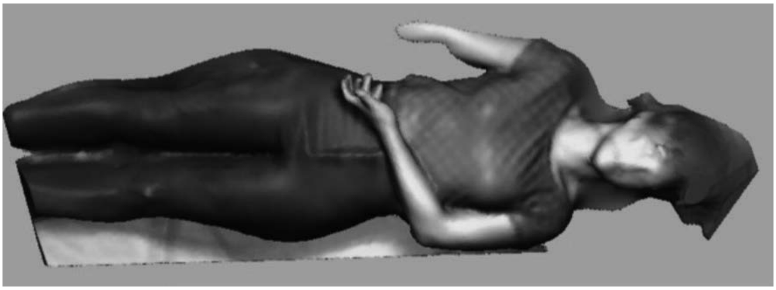

Figure 3. 3D Scan Data Capture

For the definition phase, students again focused their video presentations upon the inputs, the idea generation processes, rather than the outputs of that work. Most showed the development and selection processes but the design was not shown in detail and only one in context. For the realisation phase, students failed to present a clear final design proposal; they focused instead upon the design and production of their Makerbot rapid prototype output. Most, if not all of the supports were designed to mount the operating table or floor to the left hand side of the patient; this despite the wrist needing to support and orientation to the right. One group proposed a floor mounted support, even though the operating table needed to move during the operation for effective visualisation of the procedure.

4.2 Wider Objectives

All of the groups adopted a "hands on" approach to using the laser scanners, even if they did not use the results in their final presentations. Each manipulated their subjects into representative positions to ascertain patient comfort, flexibility and solution viability. Although initial attempts were poor and the application haphazard, each of the groups developed a working procedure for data capture.

All groups succeeded in producing from rapid prototyping, however the results were variable with problems relating to orientation on the build bed, support material and component design.

All groups developed successful workflow for creating their video presentations. Some had minor issues with sound quality, primarily related to the existing sound track prior to over-dubbing.

5 DISCUSSION

The Academic team wanted students to develop a solution that would benefit both the CIU at RBH as well as themselves through personal development. The team also wanted to trial new technologies and methods, in the form of laser scanners, rapid prototyping and video presentations.

With regard to the project objective, development of a viable technical solution, the results were mixed with some good design and development but with only a partial satisfaction of the original brief. This aspect can be tied directly to two key points: 1, failure to translate a sound PDS from the Orientation phase; 2, too much of the limited time resources directed towards the RP design rather than a viable final design. These weaknesses may be due to student's failure to reflect adequately on feedback and a desire to push on with the next stage of the project. However, the outcomes from the student work have helped to understand the practical design constraints and the academic team are currently exploring the development of a commercially viable design solution.

The project was more successful with regard to "student objectives" (1.4) or personal development through student learning, student experience and student expectation elements. Students developed a basic understanding of the design process and how to manage their personal learning. First year students learnt, through working with their second year peers, how to manage a project, meet deadlines and distil a body of work for presentation of key facts. By working directly with their peers

they have developed a good understanding of the universities expectation of work ethic and academic endeavour required for success as an undergraduate Design Engineer within the first academic week.
In discussion with 2nd year students they found, as 1st and later 2nd years, the process to be inclusive with all students free to contribute. They also felt that as 1st years they had to mix and work with the 2nd years, the relationships they established here benefiting the whole academic year. They felt, as 2nd years, it was their responsibility to get the 1st years *"..out of fresher's mode"*.
The Academic team also used PAL-Week for the trialling of new technologies; here the project was successful and students developed their video presentation workflow throughout the project. Experience gained has led to video presentations becoming the default method within the 2nd year Design Projects and 1st year Technological Principles units. From the use of 3D scanners the most interesting aspect was how the tools enabled students to become "hands-on" with physical contact and interaction between students rather than falling upon the comfort of Anthropometric data sets.
In discussion with 2nd year students they felt the scanners were *"temperamental"*, workflow time consuming and too technical to achieve good results. However, they did conclude use of the tool as a prop freed them to physically interact with each other in a way that would otherwise be uncomfortable or intimidating. They felt they *"would not have done the ergonomics"* without the scanners.

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Chapter 13

Innovation

SCULPTURAL CUBISM IN PRODUCT DESIGN: USING DESIGN HISTORY AS A CREATIVE TOOL

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ABSTRACT
In Jan Michl's "Taking down the Bauhaus Wall: Towards living design history as a tool for better design", he explains how the history of design can become a tool for future design practices. He emphasizes how the aesthetics of the past still exist in the present. Although there have been a great deal of studies on the history of design, not much emphasis has been placed on Cubism, which is a very important part of design history. Many designs of the past, such as in the field of architecture and jewellery design, took their inspiration from sculptural cubism.
The research question is therefore "How has sculptural Cubism influenced contemporary student product-design practices?" One research method used was the literature review, which was chosen to investigate what has been done in the past. Other methods used were interviews and focus groups, which were chosen to investigate what some contemporary design students knew about cubism. The researcher will also look to solicit knowledge from people outside the design community regarding designers and the work they do, as well as the general impression they have concerning design history and cubism. The concept of Cubism has been used in branding and as a marketing tool and in communication.

Keywords: Design history, contemporary design practice, sculptural cubism, aesthetics.

1 INTRODUCTION: CUBISM IN THE DESIGN PRACTICE

In Jan Michl's "Taking down the Bauhaus Wall: Towards living design history as a tool for better design", he explains how the history of design can become a tool for future design practices. He emphasizes how the aesthetics of the past still exist in the present [1]. Although there have been many studies of the history of design, not much emphasis has been placed on Cubism, which is a very important part of design history [2]. Looking into the history of design from a cubist angle can help us to understand the nature of contemporary student practices in product design. Cubism has had a very large influence on the field of art and design [3]. Now, cubism not only influences drawing but also many other areas as well. For example, it is now used in interior, architectural and product design. The research will compare artefacts ranging from the early twentieth century to the present to demonstrate the influence of Cubism. This study will show how the design process has evolved over time and explain the various transitions during this period.

2 BACKGROUND

With the emergence of new technologies like photography, the motor car, cinematography, and the airplane, artists felt the need for a more radical approach, a new way of seeing that would expand the possibilities of art, much like the new technologies were extending the limits of communication and travel [4]. Many factors influence student design practices, but sculptural cubism has played a significant role [5]. This study investigates why this is the case.

2.1 Design practice

Design is a working process with a user perspective; its development is driven by customer needs or customer recommendations. Design has become a very important tool in our everyday lives. In the book *Journal Design*, the author explains how the role of the designer is changing from someone who works behind the scenes to develop products and brands into an integral member of a company [6]. Thus, the perceptions people have regarding the work of designers is changing over time. It is becoming quite clear that people no longer see the designer as a person tasked with the "beautification of objects". The designer is now a problem solver who is able to work with companies, governmental agencies and organizations and society in general. The evolution of design practice has even become more visible as more companies and other institutions employ the services of designers.

This cycle of design history and the current nature of design are tremendously important to the future of the practice[7]. Design has a significant historical background in relation to art. Cubism forms a very important part of the history of design. Many design works, especially among product-design students, have taken their inspiration from cubism. However, not many product-design students are aware of this history and how it has influenced on their works. Knowing the history behind something is very important because it impacts your interpretation of information. It impacts the opinions you form and the decisions you make. Studying history is a very important because historical context can impact our understanding of design in a positive way.

2.2 Cubism

Cubism was a truly revolutionary style of modern art developed by Pablo Picasso and Georges Braque. Cubism derived its name from remarks that were made by the painter Henri Matisse and the critic Louis Vauxcelles, who derisively described Braque's 1908 work "Houses at L'Estaque" as being composed of cubes[8]. It was the first style of abstract art to evolve at the beginning of the twentieth century in response to a world that was changing with unprecedented speed. Cubism was an attempt on the part of artists to revitalize the tired traditions of Western art, which they believed had run their course. The Cubists challenged conventional forms of representation, such as perspective, which had been sacrosanct since the Renaissance. Cubism paved the way for geometric abstract art by placing an entirely new emphasis on the unity between the scene depicted in a picture and the surface of the canvas. Cubism is far from being an art movement confined to art history**.** Its legacy continues to inspire the work of many contemporary designers. Cubist imagery is regularly used commercially, and a significant number of contemporary designers draw on it stylistically and, more importantly, theoretically. Its innovations would be taken up by the likes of Piet Mondrian, who continued to explore its use of the grid, its abstract system of signs, and its shallow space [4].

Some cubist works are represented below:

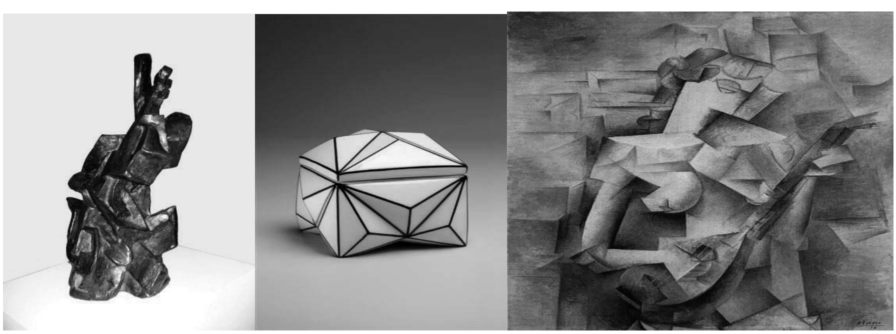

Figure 1. A B C A: Two view of the Large Horse (1914), by Raymond Duchamp-Villan. B: Ceramic Box (1912), by Bevel Janak C: Woman with Mandolin (1910), by Picasso

Images 1ABC represents some cubist works ranging from sculpture to painting, images 1AB are sculptures and 1C is a painting, it shows the role cubism played in different works. As in the artworks of famous Cubists, contemporary artists create designs with people, objects, and places, but not from a fixed point of view. Their art works often show many parts of the subject at the same time, but these parts are viewed from different angles and reconstructed into a composition of planes, colours and forms. The purpose of this feature, which is specific to Cubism, is to reconfigure space: the front, the back and the sides of the subject will become interchangeable elements in the design of the work [4]. The research question is therefore “How has sculptural cubism influenced contemporary student practices in product design?”

3 METHODS: LITERATURE REVIEW, CASE STUDY AND INTERVIEWS

The research design for this project was a combination of three research methods [9]. The research question meant I had to dive into the design field and investigate both its past and present. Each of the methods selected played a very important role in this. Qualitative research methods were employed to gain insight into research question. I employed various ways to finding information, which ranged from searching the Internet to using my own work and the work of other students to interviewing other students. The study aimed to explore the opinions people in and outside the design community held about Cubism, as well as their encounters with it in their professional practices and elsewhere. The researcher employed the literature review [10]. to examine what had already been written in the past regarding the research question. This method involves looking for information in books and other journals to build up a solid foundation of support to support my answer to the research question. Using the case study [11] as a method allowed this research to focus on particular areas of interest, allowing me to focus on the most important aspects of my research question. As a case study researcher, I had to cite professional or scientific sources that could be used to develop a new idea in my research area. I also employed two different methods of conducting interviews: formal and semiformal.

4 RESULTS OF FINDINGS AND DOCUMENTATION OF RESEARCH

4.1 Findings from literature review: Cubism and design

The first stage of this research project was the literature review. This stage was very important because it provided a solid basis for the preparation of the questions to be used in the interviews. At this stage, the researcher explored books and articles that were relevant to the research question. Some of the books reviewed at this stage included *Taking Down the Bauhaus Wall* [1], *Beyond Branding: From Abstraction to Cubism* [12], *Design Which Comes from Inside* [6], *Cartographies of Time: A History of the Timeline, and Design and Culture* [7]. These books discussed cubism and its relationship to design. Cubists proposed that one's image of an object was the sum of many different views and that one's memory of an object is not created from one angle, as in perspective, but from many angles that are selected by our sight and by movement. They also described the way in which cubism has influenced some contemporary design practices. Reviewing these books led me to a new insight regarding the research question. Some of the analysis described how Cubism had expanded the possibilities of art and design. The Cubist era had three stages, which were pre-cubism [13], analytic cubism [14], and synthetic cubism [15] which included asymmetrical compositions [16], transparency, the interpenetration of volumes and simultaneous perception from different points of view. Each were enshrined in the Modern Movement and played an important part in its evolution [4].

4.2 Findings from a case study on Cubism in product design

Researcher Robert K. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between the phenomenon and context are not clearly evident; multiple sources of evidence are used [11]. This stage of the research investigated Cubism in product design and how Cubism has affected the practice of contemporary product design. The researcher developed an account of the problem and considered the complexities that could be encountered [11]. The researcher emphasised the work that had already been done regarding the research problem [9]. As a qualitative research method, this stage involved examining contemporary real-life situations to provide the basis for the application of ideas. During this stage, the researcher also sampled design works from five product-design students to examine the Cubist elements present in them, including abstract elements and geometrical shapes. The case study [11] was also based on certain product designs that emphasise cubist elements. Figure 2 AB and C are student works that has been influenced by cubism.

Figure 2A is a jewellery box the concept for this box was influenced by nature, things in nature like leafs and the calabash which is a popular fruit in Africa influenced this jewellery box but was made in a more abstract form.

Figure 2B is piece of floor brick influenced by complicity of shape like the ceramic box by Bevel Janak , figure 1.

Figure 2C is the "Asanteman Lion" the cubism element in this piece is its abstract nature which is an integral part of cubist works.

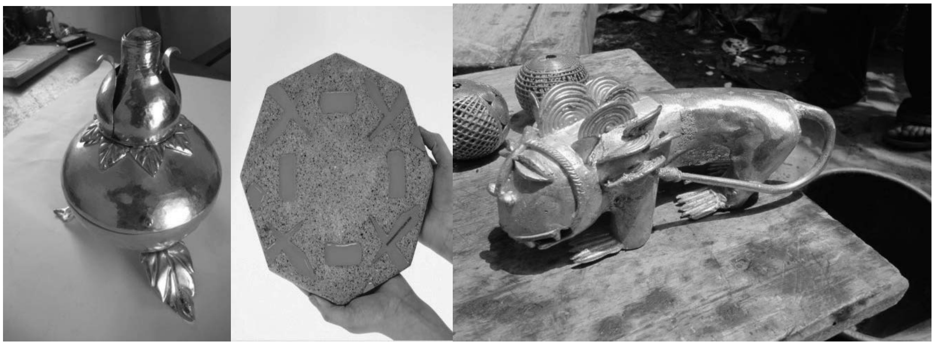

Figure 2. A B C A: A Jewellery Box, by (Augustine A. Frimpong). B: Concrete tile, by (Kjersti Holjem) C: The "Asanteman lion", by (Augustine A Frimpong)

The images in Figure 2, ABC are part of the data collected in the case study; they show how some student designs have been influenced by cubism. The findings from this participatory design shows how this stage of the research examined how certain categories of people, that is, design students and people outside the design field, view the role of Cubism in design. The purpose of this was to involve all stakeholders in design, both people who design and those who use designed works. The outcome also showed that most design students had used cubism in their works but they not know, reasons ranged from not knowing what it was to reasons such as liking the complexity of cubist works. The images in Figures 3 and 4 are images from the participatory design stage of the research.

Figure 3: Made of beeswax, this African fertility doll is a symbolic sculpture piece that stands for fertility among African women. It represents procreation, or the continuation of the generative process through childbirth.

Figure 4: This lizard is also made of wax, was made from joining together different sizes of wax balls.

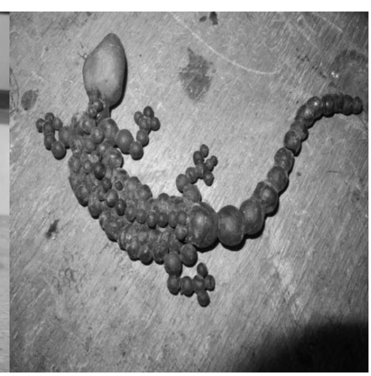

Figure 3. The African Fertility Doll

Figure 4. The lizard

4.3 Findings from interviews with product-design students

The study showed that most product-design students are not aware of Cubism and the role it has played in the history of design. Knowledge and understanding of Cubism can help design students in creating more dynamic designs. Both past and present knowledge has revealed that Cubism has played an integral role in the design process. Some students in the interviews did not know anything about Cubism, but upon explaining it to them, they did admit that it was very interesting and that they like using Cubist ideas in their designs because it makes people want to turn their heads around a design piece to fully understand its concept. At this stage, the interviews served two purposes. They educated design students about Cubism and its role in the history of design, and they also solicited information on how design students have used Cubism or been influenced by it. Figure five below shows the role cubism and the history of design in modern day design practice, on the right of the diagram is its influence on student design and the left side shows the influence in professional practice.

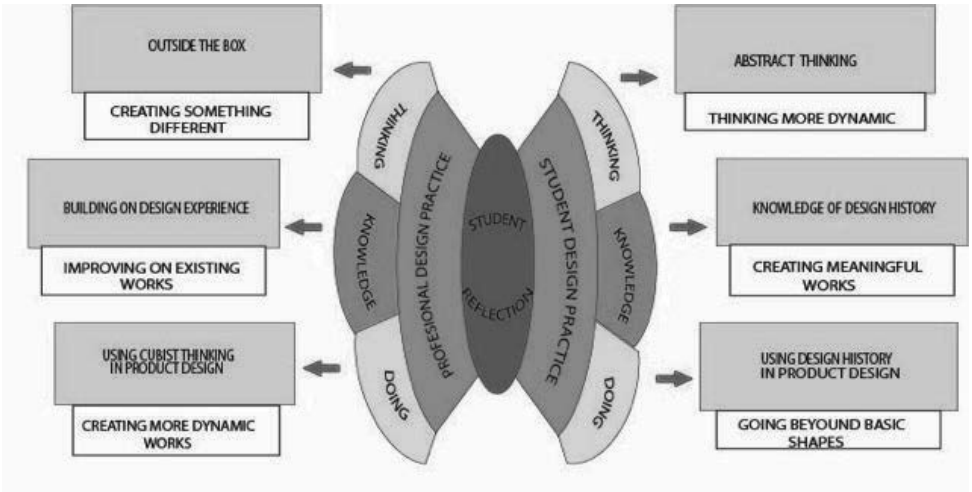

Figure 5. A visualization of learning outcomes identified in the study

5 DISCUSSION

The findings in relation to Figures 1 and 2 and the literature review show elements of cubism in some contemporary product-design students' works. They show that even though many design students are not aware of cubism, it is still present in their works. This stresses the point that there has not been much emphasis placed on the history of design [17] in design education. Though many of the students interviewed expressed their joy at working with abstract shapes and designs, they were not aware of their connection to cubism. Cubism has strong connection with contemporary product-design student works, and it will continue to play a very strong role in the future, hence the need for greater emphasis on design history in design education. This knowledge can help students understand the nature of the works they create. This leads to the conclusion of the study

The learning outcome of the various research methods is relevant to contemporary student product-design practice. Design students must learn more about the history of design. This knowledge can help them understand the meanings of the designs they create. It can also help them understand the stories of design works. Design students need to think deeply about design to create in an even more dynamic way. We should learn to see the artefacts of the pre-modernist past as a permanent presence. Because the somewhat forgotten design profession should take into account the preferences of consumers, design students should see design history as something that exists right. Considering design history in terms of the present rather than the past will turn the past into a living supply of stylistic inventions and discoveries [1].

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IDEA GENERATION: IS ILL-DEFINED BETTER FOR INNOVATION?

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ABSTRACT
It is well known that designers can tackle ill-defined and wicked problems with no apparent right solution [1] as opposed to well-defined problems with a single answer. So in Industrial Design Engineering education we focus on teaching students how to approach and deal with wicked problems without necessarily reflecting on what happens if they do not use this approach and when is the approach irrelevant. It is such in intrinsic part of the Design Thinking approach it is hardly questioned, nor clear in terms of influence on the result of ideation.
So to what extent does it influence the outcome of an idea generation whether the outset is ill defined and questioned as opposed to straightforward ideation on a proposal for a solution?
This paper discusses the results of an experiment with 32 students on idea generation and product concept development. The experiment was setup as and A-B comparison between two set of students with the same objective: designing a new coffee machine for a specific brand, but one group was asked to seek ambiguity and dissonance before creating proposals. Results indicate a very clear difference in the outcome in terms of radical changes in relation to. Group A produced 12 out of 16 proposals in the Styling category, whereas Group B only had 1 of 16 in this category.
The interesting aspects discussed in terms of Industrial Design Engineering education are: Is the deep and questioning ideation, radical innovation and conceptualization always relevant for all stages and assignments and should straightforward conceptualization be used more deliberately to increase students skills in assignments they will face in their professional career?

Keywords: Ill-defined, idea generation, conceptualization.

1 INTRODUCTION

The notion of dealing with ill-defined and wicked problems in an intrinsic part of the Design Thinking approach, especially relevant in the early phases of innovation and product development where the objectives and criteria are not locked or well-defined. E.g. the Search phase in the Delft innovation model [2]. Wicked problems are complex, indeterminate and ill-defined problems in the sense they are characterized by incomplete, changing, contradicting and interdepended information, which is difficult to gather [1][3]. Challenges like conflicting organizational pressure, tacit knowledge, complex information processing and a limited amount of information to build decisions upon, makes the early phase hard to manage, hence its characterized as ambiguous and contradictory [4][5].
In previous research on concept development within Design Engineering there tend to be a focus on how to decrease the fuzziness using elaborate process models, structured selections matrices and approach [6].
However this paper seeks to understand what the experienced fuzziness actually contributes with in the initial ideation phase and how it relates to educating Design Engineers. The fuzziness in the early phases can be divided into 2 main elements, the experienced uncertainty (especially the ambiguity) and the contradictory elements (discrepancy) [7]. Lack of information to perform the required task is called uncertainty, whereas multiple interpretations of the same phenomenon or data create the ambiguity [8], due to a lack of clarity, high complexity or paradoxes [9]. The issue is characterized by being ill defined, so the either the question or answer is unknown, hence it is difficult to search for information Additionally more information alone does not decrease ambiguity, as information is difficult to interpret.

If the elements, data or pieces of information is contradictory (discrepancy) and does not fit together, it is defined as a cognitive conflict that calls for a sense making process. As Andersson states: "*An individual's inconsistent or contradictory parts of a frame of reference about the phenomenon* indicated through *complete confusion, fuzziness, and lack of understanding* thus; there is a need for *sensemaking processes*." [7].Weick [10] points out that ambiguity and contradictory are triggers of sense making and sense-making as a driver of change. This leads to the assumption that creating new sense is an intrinsic part design process where the design gives meaning by framing experiences [10] through reflective practice [11]and questioning the intention behind immediate objectives can be a part of enlarging the solution space (Value focused thinking [12]).

The purpose of educating Industrial Design Engineers in the PBL context also revolves around the ability to navigate the fuzzy front-end, define and frame a direction for a development project and design a solution that integrates many aspects. E.g. looking at the learning objectives stated in the profile description of the Industrial Design Engineering master related to the ideation and scope of development:

- Knowledge: Must be able to explain, analyse, apply and reflect on a creative combinations of methods, technologies and approaches from various engineering fields in order to create new solutions
- Skills: Must excel in revealing and integrating explicit or tacit user needs and synthesize these needs and market opportunities into innovative integrated solutions**, in non-standard situations with complex and ill-defined problems.
  Must be able to design by integrating a desired expression and experience through form and function into technical sound products, constructions and solutions, with due consideration to state of the art technology, manufacturing abilities, costs and configuration of supply chain
- Competence: Must be able to recognize the relevant disciplines and aspects like functionality, technology, aesthetics, use, market and marketing, manufacturing, logistics, consumer, business and sustainability and is able to integrate and synthesise these aspects in the design and development of products

This clearly states the focus on the ability to deal with the ambiguity and discrepancy in the early phases of innovation. So to what extent does the ambiguity and discrepancy in the ideation phase contribute to the innovation, sense making and level of reflection in the process that is part of the profile for the Industrial Design Engineer? Based on a laboratory experiment this paper investigates the effect of deliberately seeking ambiguity and discrepancy in the initial ideation phase.

2 METHOD

The hypothesis is that an approach to ideation where ambiguity and discrepancy deliberately is sought creates more radical innovation that an approach without this. Using a straight proposal creation process is expected to create proposals that operate within the present sociocultural meaning. Whereas an approach seeking ambiguity and discrepancy in the initial ideation sparks a deeper sense-making process, which in return creates proposals that can be interpreted as having new sociocultural meaning in line with Vergantis [13] definition of radical innovation.

To investigate the hypothesis validity a laboratory experiment is set up, to test the difference in solutions from respectively a straight proposal creation process and a process where ambiguity and discrepancy is sought before creating proposal.

2.1 Participants

Choosing participants for the experiment was primarily done looking at the experience level. They needed to have a basic skill set in drawing and understanding the construction of products to be able to create a conceptual proposal. But they could not too experienced, so they would revert to a processes including questioning or reframing the assignment by default. The participants in the experiment were a group of 32 1st. MSc. Industrial Design Engineering students.

2.2 Experiment setup

The students are randomly divided in two groups (A&B) of 16 participants each and both groups are given the same basic task, to create proposals for the next version of a coffee-machine for specified firm. In order to be able to analyse the change in sociocultural meaning the coffee machine assignment was chosen because of the archetypical sociocultural meaning of this product in the Danish culture.

Group A are instructed to seek ambiguity and dissonance before creating proposals and Group B are the control group that are asked to just create new proposals. The groups get an equal amount of time and are asked to deliver proposals in the same format. Table 1 shows the overview.

Table 1. Comparison of task and process of groups A and B

	Group A	Group B
Task	Develop a new product concept for a Melissa Coffee machine 2015	Develop a new product concept for a Melissa Coffee machine 2015
Process instruction	Straight proposal-making Instructions to go straight to solution mode	Deep sense-making Instructions to seek ambiguity (in how) and dissonance (in why) before going into solution mode.
Process delivery	None	Why paper: Midway deliver a A4 paper, pitching a number of contradictions concerning the current concept
Deliver	Proposal: A3 paper, pitching the final concept All working paper including initials, timestamp and notes	Proposal: A3 paper, pitching the final concept All working paper including initials, timestamp and notes

3 ANALYSIS

Based on the expected change in sociocultural meaning in the proposals using the approach of seeking ambiguity and discrepancy the 3 main evaluation criteria are changes in Product Category, Use Scenario and Product Architecture. Using a short laboratory experiment without a context of company, market and users, the main evaluation on change is relative and subjective compared to the outset, in this case a traditional tabletop home based filter coffee machine. The concept of change is therefore subdivided into the following 2 categories in Table 2

Table 2. Criteria of Insignificant meaning (left) vs. Significant new meaning of proposals

Insignificant or no new meaning	Significant new meaning
I.1 The proposal is a filter based coffee machine to be put on the kitchen table at home.	S.1 Goes beyond the original product category, i.e. differing from a filter based coffee machine to be put on the kitchen table at home. This would change the perception what the product is, albeit the evaluation is relative to the given starting point and not screened and tested on the market in this closed short laboratory setting.
I.2 And there is no change is the use scenario	S.2 And/or the proposal implies a significant change of the use and scenario of use of the product relative to the starting point.
I.3 And there is no significant visible or understandable change in the product architecture compared to the given coffee machine that implies new functionality.	S.3 And/or the proposal in compared to the given coffee machine significantly changes the relation and positioning of the internal and external components in the machine, or changing/adding/deleting components that would be visible or understandable for the market/user.
I.4 Or if the change/newness relates only to shape, colour and size but remain in the product category.	

3.1 A-B comparison

The initial difference between group A and B's proposals is evident in the number of proposals that are variants of the filter based coffee machine.

- Group A has 12 of 16 proposals that are variants of the filter-based coffee machine

- Group A has 4 of 16 proposals that are creating significant new meaning.
- Group B has 1 of 16 proposals that are variants of the filter-based coffee machine
- Group B has 15 of 16 proposals that are creating significant new meaning.

In more popular terms the majority of participants in group B are thinking ‘outside the box’ compared to the original reference point.

3.2 Group A

A closer examination of the 12 proposals in group A that looks like variants of the reference filter based coffee machine reveals the main ‘newness’ is related criteria I.4 for insignificant change in meaning concerning shape, colour and size. Proposals A. 3, 5, 6, 7, 8, 9, 12, 14 and 16 (Fig.1, left) all relate to this criterion. A.2 and A.10 have minor changes in the product architecture (criteria I.3), concerning the positioning of the water container (behind or above filter) and the change the use scenario is insignificant (I.2) and it is still perceived as a traditional filter based table top coffee machine (I.1).

The 4 proposals with significant new meaning in group A are A.1, A.11. A.13 and A.15. In A.1 the use scenario is altered (S.2) to a “His and Her” coffee machine and the product architecture altered (S.3) to a twin-cup and twin water container structure. A.11 changing the product architecture significantly (S.3) by rearranging and removing components like the disposable filter and introducing a steaming principle that leads to a new use scenario (S.2).

In A.13 the proposal is changing product category to capsule-based coffee machine (S.1) and A.15 is changing and revealing the product architecture in a new transparent way (S.3) and hanging the machine on the wall differs it from the reference table top based machine (S.1).

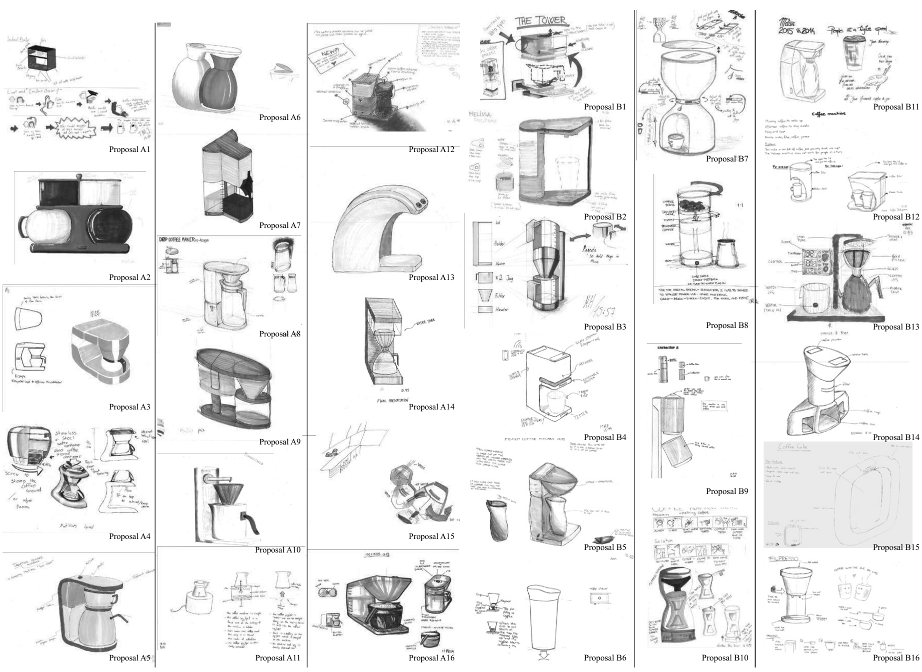

Figure 1. Sketches from group A (left) and Group B (right)

3.3 Group B

The main newness in the 15 variants of group B that are evaluated as significantly different are primarily changing the use scenario (S.2) adopting it to a different situation and creating a new experience/interaction with the coffee machine compared to the original filter based table top coffee machine. One category of changing the scenario is the coffee-to-go in proposals B.2, 4, 10 and 11 (Fig 1, right) or the scenario of just making 1 cup at a time in proposals B.7, 12, 14, 15 and 16.

2 Proposal changes the product architecture and functionality (S.3), in proposal B.6 so the coffee rise from the bottom of the brewing cup to create a new surprising effect (S.2). Proposal B.8 integrates coffee bean churning by hand (S.2) and a pressing piston mimicking a French press (S.1 and S.3).
In two proposals B.3 and B.9 the immediate visual reference seems to be a more traditional filter based coffee machine, but reading the comments at the sketches in B.9 discloses a change in the functionality (S.3) that allows the machine to dispense coffee like a tap. This leaves B.3 as the only one without any significant changes in the sociocultural meaning.

3.4 Additional findings on reflective practice

Examining the two groups also revealed another significant difference, proposals from group B in general had more comments and text on their final proposals than group A. Asking group B for an intermediate written description of the ambiguity and discrepancy that they have identified, may have triggered a more reflective sketching practice throughout the entire session.
Looking at the text in the sketches it shows that the text is commenting and reflecting, like Schön [11] describes in the reflective practitioner: *"In a good process of design, this conversation with the situation is reflective. In answer to the situations back-talk, the designer reflects in action on the construction of the problem, the strategies of action, or the model of the phenomena, which have been implicit in his moves."* (pp.79).
This indicates the elevated level of reflective practice is related to the higher number of radical new proposals with an articulated meaning and purpose, as well as created a more focused proposal with a higher sense of direction.

4 DISCUSSION

The obvious significant difference in the approaches of straight versus ambiguity and discrepancy oriented ideation and conceptualisation is the significant higher level of radical different solutions when seeking ambiguity and discrepancy. Within the very limited experiment the conclusion seems to be very clear, it leads to more innovation if the designer seeks to question the framing and scope of the task.
However there are of course some consideration concerning the experiment that would question the extent and level of innovation. In the experiment the measurement of innovation is only relative to the reference product given to the participants. Even though it represents an archetypical product that relates to a certain old fashion coffee drinking culture, the proposals deviating from this reference point cannot be said to be absolutely new to the company, the market or the world. The feasibility of the proposed constructions is not taking into consideration either, leaving some of the 'innovative' proposals questionable and potentially unrealistic. But it does not eliminate the fact that the two approached produced significantly different results that only can be contributed to the difference in instruction and approach.
In the evaluation of creating new meaning, the aesthetics in terms of visible features like size, shape and colour have not rated as high impact in regard to creating new meaning making as changes in the use scenario and functionality. This validity of this distinction could be questioned with regards to Verganti definition and examples, but it is very relevant when looking at the development of new products as an activity that integrates multiple disciplines and perspectives and not just styling products. In this perspective it aligns very much with the learning objective of the Industrial Design Engineering Masters profile as stated in the introduction, especially in the competence learning objective: *"…functionality, technology, aesthetics, use, market and marketing, manufacturing, logistics, consumer, business and sustainability and is able to integrate and synthesise these aspects in the design…".*
The side effect of increasing the visible reflection in the process as the notes and comments on the sketches and proposals demonstrates, is also a requested ability of an Industrial Design Engineer. This is especially evident in the knowledge learning objective: *"…explain, analyse, apply and reflect on a creative combinations of methods, technologies and approaches from various engineering fields in order to create new solutions."*
So seeking ambiguity and discrepancy in the ideation phase aligns with the intention of educating Industrial Design Engineers that by default will challenge the initial framing of the task in order to open up the potential solution space and seek innovative solutions on more radical level.

On the other hand one could then question the relevance and validity of this approach when acting in the profession of product development. It may not always be relevant for the client or company the Industrial Design Engineer work for to seek radical new solutions rather than incremental new solutions. One could argue that the holistic approach of also integrating manufacturing capability, market and business aspects would then balance the quest for innovation with the actual possibilities.

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INNOVATION AND ACADEMIA — IPR OWNERSHIP IN THE UK

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ABSTRACT

This paper discusses Intellectual Property Right (IPR) ownership issues in conjunction with academic spinouts and start-ups. The changes in the funding structure of graduate and postgraduate studies has led to a culture shift in the budget management of British universities. Third-income streams are more highly rated in the UK than ever, and 'with the growth of the student enterprise agenda the issue of management of student IP will become increasingly significant' [1].

Commonly academic institutions claim ownership over IPRs, which evolve from postgraduate academic studies. The majority of revenues tend to go to the academic institution. This is usually justified through the supervisory involvement and the provision of technical resources. This paper discusses the implications, which the retention of IPR has for the success prospects of academic spinouts.

Academic Institutions differ in their approach to regulating IPR ownership. Mandy Haberman and Professor Ruth Soetendorp presented a comparative study of academic regulations to the Intellectual Property Awareness Network (IPAN) in 2014. The paper proposed here builds on their comments as well as those obtained from various subject experts through semi-structured interviews. The paper will further discuss the implication of third-party ownership in relation to the development of innovative spinouts. Counter-productive arrangements in relation to IPR ownership made by academic institutions may not only affect the individual graduate or postgraduate student, they may also affect the UK economy, in that they can stifle innovation.

Keywords: Innovation, management, intellectual property, start-up, graduates, academia.

1 INTRODUCTION

In a Q&A session following a keynote speech during the International Association of Societies of Design Research (IASDR) congress in Tokyo in 2013, the speaker, Professor Göran Roos, claimed that the vast majority of business founders are final year MA students, or first-year PhD students [2]. The potential for creative entrepreneurship amongst postgraduate design students is greater than elsewhere within the spectrum of the design industries. The question is whether or not this potential is used to the best capacity. We can identify 3 key stakeholders here:

- The students
- Academic Institutions
- The general public who may benefit from innovation.

This paper discusses how regulations surrounding academic IPR ownership suit the interests of these stakeholder groups, and where they can lead to conflicts. It builds on a presentation, which Mandy Haberman, a successful designer entrepreneur, and Professor Ruth Soetendorp, Associate Director of the Centre for Intellectual Property Policy and Management at Bournemouth University, gave to the Intellectual Property Awareness Network (IPAN) in 2014. Both are listed as co-authors due to the extent to which this paper has been influenced by the presentation notes and following discussions about the topic. The co-authors' personal views are presented in the form of citations here. To embed these views in a critical context, the main author has conducted literature reviews and interviews with subject experts.

2 PERSPECTIVES

Haberman's interest in academic IPR management was prompted by an experience in 2013, when she was part of the judging panel for the Design in Plastics Award [3]. When speaking to representatives of Northumbria University, who submitted one the winning entries, she was led to believe that the IPR rested exclusively with the academic institution. She was also told that the institution made little effort to formally protect IPR generated through the efforts of graduating students. Upon further investigation Haberman found out that Northumbria's IP Policy 'recognises undergraduate students [who are not employees of the University] as the owners of any IP generated during their studies subject to exceptions', and that 'The University is committed to the effective exploitation of IP' [4]. The policy stands in contradiction to the verbal statements received, because the competition winners from Northumbria had been undergraduate students. This raises questions about the level of awareness for existing regulations amongst staff and students.

The inventor of a fibre optic sensing technology, who studied at Cardiff University criticized university IP agreements for being not sufficiently beneficial for inventors [5]. She described the IP agreement that she was offered by the university, and which she rejected as 'rigid and out of date' [6] Peter Brewin, co-founder of Concrete Canvas, an innovative materials firm that was designed during his studies at the Royal College of Art stated that 'although universities could be helpful in allowing access to equipment and office space, taking too large a stake in a company, especially when not directly investing in it, risked "killing" the idea' [7]. Concrete Canvas is an invention that originated in the design of a shelter, which Brewin and his project partner Will Crawford had conceptualized and patented whilst studying at the Royal College of Art in 2005. But, as in so many cases, it was not their first invention that led to commercial success, it was the fabric, which was patented 2 years later. This shows that it is not so much the idea per se that is key to success, it is the continued pursuit of an the implementation of an idea.

Figure 1. Concrete Canvas used for slope lining

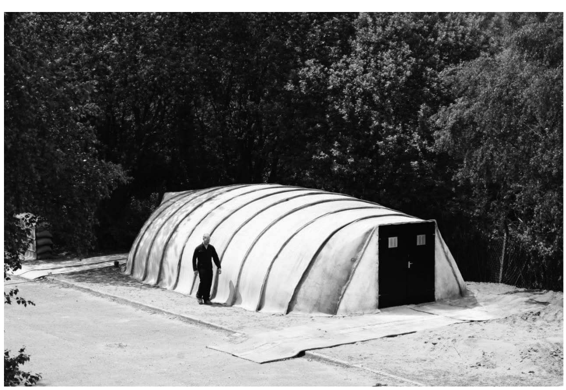

Figure 2. Concrete Canvas was originally designed for shelters

The question we are left with is whether or not academic institutions ought to claim ownership over IPR generated by their students. In an issue of the Indiana Law Journal from 1995, Sandip H. Patel points out that ‘Universities […] view the continued exposure to research activities and classroom instruction as adequate consideration for an assignment of ownership rights’. [8]. Is this fair, given that students in the UK are now paying considerable fees for their education? What justifies such fees, if not the exposure to research activities, classroom instruction and university equipment? According to Phil Chan ‘The argument that pedagogy constitutes consideration capable of vesting in the university copyright ownership in its student’s academic work is untenable’ [9]. Chan’s reasoning is based on Patel’s point that ‘the student who fails to develop a patentable invention is never held liable to the university for a breach of contract’ [10]. The justifiability of resting IPRs with academic institutions as opposed to transferring them to students can therefore be questioned.

Although undergraduate students usually get to keep their IPR, postgraduate students may be treated in the same way as are employees of the institution. This may be as a result of the postgraduate signing a contract specific to a funded research project, which determines the way in which ownership of resulting IP and division of any income generated will take place. Mere assumption that the postgraduate researcher is an employer can be seen as questionable, if not to say unethical. After all their initial contract with the university is not to ‘provide services or undertake duties in a way that gives rise to a situation in which their work could be considered as arising from employment’. [11] The UKIPO's guide to ‘Intellectual Asset Management for Universities’ makes it clear that these arrangements are left up to the individual institution [12]. Consequently the treatment of student IP can vary, in particular with regard to profit sharing. The UKIPO advises that a ‘policy rationale needs to be established so that not only the individual interests of the fee-paying student are accommodated but also to ensure that their ability to contribute to the economy and society after they graduate is not compromised. ‘Having clear policies about students’ abilities to use the IP they generate, combined with mechanisms which actively support them in doing so, are therefore important.’ [13] Although academic IP policies per se may be clear on paper, it is evident that they are not fully understood.

The ignorance surrounding academic IPR management is not helped by the fact that IP education, i.e. the inclusion of intellectual property as a module topic, is usually not part of the design curriculum. Haberman and Soetendorp highlight that they have encountered very few other than ‘Bournemouth University that has put IP education modules on the curriculum of undergraduate courses, other than for law students’ [14]. Imperial College’s spinout EPIGEUM’s online resource Research Skills Master Programme has a module ‘Intellectual Property in the research context’ [15] which emphasises that ownership of any resulting IP should be discussed at the same time as a research project and research funding are being discussed. The IPO in 2015 launched IPTutor, an online resource for university students. [16] Most major institutions have an IP policy document but few members of staff are aware of its existence, let alone its content. The fact that IPR ownership is subject to the discretion of individual institutions means that certainty can only be established through the examination of individual IP policies, which tend to be complex and often vague. The current Manchester document is 66 pages and even design experts may find it difficult to follow. In addition to the problem surrounding transparency or the lack thereof, Ian Shott, Chair of the RAE Enterprise Committee, claims that many academic technology transfer offices ‘were too small to justify their cost, and each with “very prescriptive processes” run by inexperienced people’ [17].

The above analysis raises a number of questions:

- Are university IPR regulations fair?
- To what extent are staff and students aware of IP policies?
- Even if students have sight of the policy, would they understand it?

The low level of awareness of IP amongst students is evidenced in a study which the National Union of Students (NUS) has conducted in collaboration with IPAN in 2012 [18] and forms the basis of a research project being conducted by NUS and the IPAN on IP Policies – perception and practice.

3 THE UTILISATION OF IP

When discussing the share of profits, Haberman points out that ‘most universities will state that where student IP is part of a project that is commercialised, the university will share profits with the student. However, instead of defining how these profits are to be split, non-specific terms such as ‘revenue sharing arrangements on a fair and reasonable basis’ are frequently used [19]. So there remains a lack of clarity about how profits are to be shared. Another problem is that IP seems to be regarded as a guaranteed source of revenue income. However, before fighting over potentially profitable returns, one should ask what is required to commercialise inventive steps in the first place. It is important to understand the difference between inventions and innovations here. According to Greenhalgh and Rogers an invention is a discovery that 'enhances the stock of knowledge', whereas an 'Innovation occurs at the point of bringing to the commercial market new products and processes arising from both existing and new knowledge.' [20] In other words, an innovation is the successful application and commercialization of an invention.

When students exit university, their inventions tend to be so underdeveloped that they have a long way to go until they reach market. Therefore one should focus not only on profit shares, stakeholders should also contemplate who takes the responsibility of financing and pursuing the design development and the route to market. If this is the academic institution, then we could genuinely speak of a spinout. However, if the student is left with the challenge to develop the operations and assets needed in order to take an invention to market, then we ought to consider this as a start-up venture instead. Incubation schemes make it often difficult to differentiate between start-ups and spinouts. Nonetheless the give-and-take must be balanced, and university IPR management ought to facilitate the route to market instead of adding barriers. Without having direct control over the IPR, a designer-entrepreneur does not have the authority to enter strategic partnerships, which may be needed, and investors can be reluctant to commit to the venture. Hence the retention of IPR by the academic institution can make it very difficult for start-up ventures to succeed.

According to Haberman and Soetendorp's findings 'Some universities don't use a blanket assignment but instead, evaluate each instance on its own merit. This allows for more flexibility but even then, the institution makes the decision on how profits are split.' [21] The fact that undergraduate IP is usually granted to the student, and postgraduate IP retained by the academic institution highlights how pragmatically-driven the design of regulations tends to be. Undergraduate IP can seen as lower in value, because undergraduate students tend to be less experienced than postgraduate students, and their novelties are often less developed or promising than those emerging from postgraduate studies. If we look at the situation from a pedagogical point of view, we realise that designs developed at undergraduate level are nurtured to a greater degree than those, which are developed at postgraduate level. If we try to judge the situation without bias, we should think that it would be fairer to assign IP generated at undergraduate level to the academic institution, and IP generated at postgraduate level to the student, due to the greater supporting efforts provided through academia.

4 IMPLICATIONS

Universities often argue that they need to own postgraduate student IP if it is part of a bigger research project (which may be funded by industry) so they can cleanly enter into binding agreements with sponsors and licensees for the commercialisation of the entire IP package. However, if there is no direct industry involvement at the outset, and the innovating graduate seeks to commercialise the invention, this rule can produce insurmountable barriers. The reason why this discussion culminates in an insoluble challenge, has its roots in the disconnection between IPR and innovation management. IPRs per se constitute no value according to venture capitalist Carlos de Pomme. 'What IPR does, is that it gives you the ability to create value. These are very different principles, and IPR gives you the ability to defend future revenue streams.' [22] The reason why there is no coherent approach to academic IPR management is due to the fact that there are no communalities in the route to market strategies. Any regulation that seeks successful adoption through academia, must regulate IPR ownership in relation to the requirements that relate to the commercialisation of an invention. Depending on the circumstances and the nature of the invention, the graduate or the academic institution may be in the better position to take responsibility here. Where the IPR is assigned to one party or another, that party should also be assigned the responsibility of commercialising the innovation, and to provide royalties to the other. If the IP holder decides not to commercialise the innovation, it would benefit the greater public good if the other party were given the right to have the IP transferred.

5 CHALLENGES

Academic institutions differ in size, and the larger they are, the more complex the decision making process tends to be. They usually lack the agility of small firms. When discussing collaboration in conjunction with innovation management, Mark Dodgson highlights that 'Small firms […] can be flexible and responsive to new market and technological opportunities in ways large firms cannot, and one of the benefits of collaboration is that it combines the entrepreneurial behavioural advantage of the former with the structures and resources of the latter' [23]. This would suggest that a collaborative arrangement between a start-up led by one or several graduates and academic institutions could work well. However, despite the benefit of the weight of a large organization in support, having to give up the authority over key decisions such as licensing opportunities and collaborative arrangements, which are dependent on IPR, can be demoralizing for the enterprising academic, and it can also slow down operations and business development progress. The confusion surrounding IPR ownership in relation to design teaching and learning is counterproductive to the pursuit of collaborative arrangements between graduates and academic institutions. Alexy and Dahlander explain that, 'The more strongly enforced the legal mechanisms that define ownership over intellectual property along clearly demarcated boundaries, the easier it will be for two parties to contract over the exchange of innovation' [24]. The problem is that the British higher education system does not draw clear demarcation lines with regards to IPR.

What discussions surrounding IPR management often omit is the fact that innovation requires not only inventive thinking as it is fostered through the provision of design courses, it also requires design and business development activities. This means that the concept of innovation comprises not only the inventive step, but also the successful application and implementation of an invention. Therefore the question one may want to raise over and above the discussion surrounding IP control, is which set of circumstances is most beneficial for the innovation process to succeed and the general public who seeks to benefit from it. We must acknowledge the fact that a lot of design ideas and concepts are underdeveloped when they go on display during degree shows, requiring a considerable amount of further development to take them to market. Institutions are may be in the better position to deploy assets needed to further develop design concepts. On the other hand one could argue that graduates find it easier to commit their time to the innovation process. Academics are confronted with a plenitude of responsibilities, which makes it difficult for them to focus their attention exclusively on one particular invention, and to do so over several consecutive years. Graduates will find it easier to commit their time to the pursuit of innovation, provided that they can hope to be rewarded for their time commitment.

6 CONCLUSION

The evidence discussed above is insufficient to come to a conclusive verdict whether or not there should be a nation-wide policy that is to be adopted by all academic institutions, or if the latter should continue to decide individually on IPR ownership and in doing so, perhaps adopt a more flexible approach to accommodate the interest of students. It is clear that current regulations and their diverse applications have led to a confusing situation. This is due to the fact that most academic institutions tend to retain ownership of IPR generated by postgraduate students while they often transfer to students the IPRs generated through undergraduate studies. Depending on the circumstances, the IP generated by undergraduates can also be retained by the academic institution. The confusion surrounding academic IPR ownership is shared amongst both staff and students, because the decision is left to the discretion of individual institutions, whose IP policies are not always sufficiently clear.

It would be advisable to conduct a comparative study not only with respect to current university policies, but also in relation to their implementation. This should be done through screening a representative sample of academia in the UK, and through comparing the success and failure of academic innovations at undergraduate and postgraduate level. It would be desirable if the UKIPO could commission such a study. The problem of academic IPR ownership is likely to have an adverse effect on innovation in the UK and on the attractiveness of studying in the UK. It might also impact on the UK economy in the small business design sector. The aim of such a study should be to establish whether or not it is preferable to have one policy adopted consistently by all academia in the UK, and how this IPR policy ought to be applied.

It is unlikely that assigning 100% of the IP to either the innovating student or the academic body, solves all the problems involved in academic IPR management. However, the authority over IPR and the responsibilities in relation to it, ought to be made clear from the outset, because this helps to identify the responsibilities involved in pursuing innovations, and provides a basis for specifying the roles which both parties, academia and innovating students, are to fulfill. If one or the other seeks not to engage in the innovation process, the IPR can be transferred in return to a royalty, which, too, ought to be considered as part of the regulations. The current situation is often perceived as a competition between graduates and academia. A fair and clear set of regulations could help turn this into a concerted relationship between the stakeholders.

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DEVELOPING INNOVATION IN HIGHER EDUCATION: THE CATALYTIC EFFECT OF CONFERENCE ATTENDANCE

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ABSTRACT
Educational innovation through conference attendance is the main theme of this paper. It starts by describing and contrasting product and education innovation, highlighting the importance of the step of influencing and determining the future direction of the market or community of practice. It goes on to describe the important learning processes associated with copying, affirming its importance in the way that educational innovations spread and develop. The paper includes several personal examples where ideas have been copied and developed following E&PDE papers. The paper poses a further question regarding the place that subconscious innovation takes place, treating it as a topic for further research.

Keywords: Product innovation, educational innovation, copying, conference attendance.

1 OVERVIEW AND BACKGROUND

1.1 Background

The feedback form from a recent conference asked the question “What action (or actions) have you taken away from the day?” [1] The suggestion from this, of course, is that conferences are there for ideas to change the way that things are carried out – a good point and very valid.

The inspiration originated from some comments regarding the usefulness of attending conferences and other educational meetings such as course validations and accreditations. This focused on how effective practice might be identified and be incorporated into the teaching. A colleague claimed his approach to these occasions was to identify which ideas he would like to steal and inform the person he was going to steal them from, asking for permission.

1.2 Conferences

One of the least useful sorts of conference is where presenters arrive solely for their paper presentation and then immediately depart, depriving themselves of the opportunity for interaction and networking as well as learning and developing their practices and techniques, and becoming engaged in providing meaningful contributions during question sessions, both formal and informal. The contributors may obtain publications, but they have neither been influenced nor been allowed to influence the conference community significantly.

Another type of conference has limited time and facilities for interaction: a packed schedule, a huge number of erudite papers in many parallel sessions, noisy lunch and dinner sessions and introverted attendees who are not interested in discussion.

It would seem that the E&PDE community, whilst being reasonably large and having several parallel sessions, seems to have avoided these mistakes. Although the papers are certainly of reasonable quality and current, they do not necessarily consist of the latest piece of research that has just been published in an erudite journal and presenters are not usually trying to compete with each other. They are usually applied to educational situations that are relevant for ninety per cent of the attendees, and hence they tend to promote discussion and comment. They should promote effective educational innovation, changing the face of the subject area and community, and if possible influencing those outside as well.

This does not mean that a conference does not have other purposes, such as to provide students and early-years academics opportunity to present their work, and here E&PDE also seems to be more tolerant and helpful than many other conferences. There doesn't seem to be the competitive atmosphere that sometimes pervades.

1.3 The theme

The main question the paper seeks to address is, "How might conferences such as the E&PDE conference engender effective educational innovation?" And, in particular, how individuals might use it to develop effective innovation.

Similar questions might be posed to the organisers, focusing on the theme and programme.

The paper is not intended to address the general benefits of conference networking, presenting papers or the extent to which an attendee's subconscious is developed and changed by attending the conference and meeting the community, which may in itself lead to innovatory practices. This latter could be the focus of further work.

2 INNOVATION

2.1 Definitions

Product innovation is not generally a clean, clear tidy process. No particular method will unfailingly result in effective innovation [2]. There may be a number of pointers, common ground and general stages that need to be covered, however.

Abernathy defines innovation as a major improvement or series of improvements in a "design approach"[3]. Kumar [4] defines it as "a viable offering that is new to a specific context and time, creating user and provider value". Abernathy's definition only refers to the novelty aspect and not viability or value: Kumar's definition includes the two aspects of novelty and value. This tends to be more in line with other definitions.

Here innovation is defined not simply as that which is new and different, but also, crucially, that which is new and different in ways that determine future direction of the product market or industry and which therefore offer leadership. This requirement of innovation to be imitated adds to both definitions above and is not generally included within traditional definitions.

2.2 Innovation in product design

Historical hindsight is a very effective way of determining which products have been innovatory. It may be difficult to identify these at the time.

Several examples of innovation have been documented, such as the developments within computing that led to disruptive innovations of the personal computer [5], the turbojet [6] or the manufacture of float glass.

However, innovation takes place even when not disruptive in character. Here it is clearer that the changes that produce innovation are those changes that pass from one company to another as freely as possible, without the interruptions and blockages that might be created by the patenting system. For instance, in the motor industry, patenting issues, although important, are ineffective because the real innovation – the aspect that can be copied – is something that is not novel but which was not copied significantly, and where patent protection would be weak. Layout arrangements tend to be freely copied, and distinctive manufacturing methods are licensed or distributed across companies (such as Budd's influence between 1910 and 1935) or are aspects which cannot be patented, such as the use of independent suspension where patents can only be applied to particular embodiments.

The evidence from a car history is that producing a different car is not enough to be regarded as innovative [7]. It must also meet a real need and be produced in reasonable quantity, and other car manufacturers must perceive features as worth copying.

2.3 Innovation in education

Higher Education currently faces three significant challenges and these are driving innovation, in the main. These are (i) pressures from globalisation; (ii) changing supply of and demand for higher education; and (iii) changes in higher education funding. Whilst innovations also result from people and groups of people feeling they simply have 'a good idea', they may not be successful unless they fit this environment [8]. They may be developed by individuals, institutions or collaborative ventures between institutions.

However, a significant number of educational innovations are from individuals who have great ideas and who put them into practice in their own setting, get them to work and then publish them. Frequently there is no real design process – educators tend not to be designers. The second stage is still the equivalent of product prototyping or pre-production stage, and production of the innovation is left to publication and copying. For successful innovation in education the copying process is the major way that the innovation is and realised. This is the key stage for successful educational innovation. This last stage of idea dissemination and planting the novel concept into fresh soil are the most important features of educational innovation [9]. A significant requirement of such planting processes is that the idea must be allowed to become naturalised and must lose its 'not invented here' characteristics; it must be owned, embellished, customised and adapted, for its new soil. In particular, it needs to spread beyond the boundaries of the institution where it was first used [8].

Thus, for instance, the concept of Active Learning perhaps had its gestation with the development of the studio culture, originating in places such as the Arts and Crafts schools, revisited by the Bauhaus, discovered as a good idea and published by Schön in his Reflective Practitioner [10] in 1991, and by Bonwell and Eison in the same year [11] by which time a significant number of Art Schools and Product Design courses were already using it without necessarily using the Active Learning term. The concept has been revisited many times, each visitor claiming to make it their own each time they rediscover it.

3 EFFECTIVE USE OF COPYING PROCESSES

Educational innovation is heavily dependent upon the effectiveness of copying used to disseminate its initial usage. Copying has long been utilised in education. The Adelphi Charter on intellectual property developed by the RSA reads:

> Humanity's capacity to generate new ideas and knowledge is its greatest asset. It is the source of art, science, innovation and economic development. Without it, individuals and societies stagnate.
>
> This creative imagination requires access to the ideas, learning and culture of others, past and present. And, in the future, others will use what we have done. Human rights call on us to ensure that everyone can create, access, use and share information and knowledge, enabling individuals, communities and societies to achieve their full potential [10].

This access to ideas, learning and culture is not really simply 'access'. The access needs to allow copying, changing and developing those ideas and culture both consciously and subconsciously.

At some points within the guild and apprenticeship schemes the pejorative moniker of 'sitting with Nellie' was used to describe this learning by copying process, but in fact this was a highly respected educational tradition. There is a single word in Japanese that has something of the same feeling – that to learn is to copy. But it is not quite that simple, as translators from any language will be aware. The Japanese concept is one of mastery. The concept is developed in papers collected by Singleton[12], largely based on experiences in Japan and describing learning that takes place in non-traditional settings. In this particular copying the master is first accurately identified. Then the master's works are identified and their tradition and learning processes identified: how their work has changed and developed. The next stage is to accurately copy every nuance of the master. This stage takes some considerable time, and some of those engaged in it, particularly if from a Western tradition, tend to get bored with the process and want to carry out something different [13]. The next stage, of course, is to seek to make the genre and process one's own, utilising the nuances subconsciously imbibed during the learning process. Almost to prove that the copying stage is imperfect, Dulwich Art gallery recently included a fake work of art produced by the Meishing Oil Painting Manufacturing Company in their gallery, asking visitors to identify the copied painting [14, 15]. In the BBC News report of the exhibition John Myatt, previously an art forger, was asked to identify the particular painting and although the one he chose was not identified, he described the unnatural use of brush strokes and technique as being how he would identify it [16]. Brush strokes tend to be developed and learnt subconsciously during that long copying period as the nuances of the original master become understood.

4 CONFERENCE ATTENDANCE

So how might conferences be part of the process of developing innovations in education? And how, in particular, might this conference be an effective part of developing educational innovation?

The general principal appears to be to clearly identify the mastery that embodies the innovation. This may be a singular insight from a particular contribution: it might be how something becomes part of a different embodiment, after the conference. The principle is the same. It is to find something or things, in the opinion of the attendee, worth copying into their general vocabulary, worth becoming part of the subconscious toolbox that each educator carries around with them. It may be worth talking with the presenter and informing them of your desire to copy their ideas. Usually, this will be encouraged – after all, this is not exactly theft, but is part of the educational innovatory process. There could be several outcomes from this 'theft'. Often, that encouragement identifies the original idea to be worthwhile, when the original owner may have doubted it. An interesting outcomes is where the 'theft' results in collaboration and joint work, developing the innovation to be more credibility.

4.1 Examples

These tend to personal examples for the simple reason that knowledge of them is easily to hand – it includes personal memory of having been consciously and deliberately involved in the copying. They will also be limited to the Engineering and Product Design Education conferences.

4.1.1 Design coaching

In the 2003 conference a paper was presented that developed a hypothetical view of developing an individual's product design skills based on a sports coaching model [17]. The approach developed, several years later, into a funded project on Design Coaching. The title was there, but the project took a completely different turn, whilst relying on the original paper for inspiration. Coaching ideas were amalgamated to result in a joint paper, combining different approaches, one from personal experience of archery coaching and the other from the funded project, which developed future views and visions for a group of design staff rather than taking a student view [18]. The gestation from the stolen idea to the embodiment was a rather long four years, and it changed and developed significantly.

4.1.2 Future gazing using utopian science fiction

An Australian group project on future gazing was presented [19], where students were used utopian science fiction to develop food product concepts for 75 years hence. The theft took the idea of using utopian science fiction, kept the group project, but changed the product area from food to urban transport and the time span from 75 years hence to a more lowly 50 years. The first recycling of this project took a rather shorter time – it was reported in the next year's conference [20], complete with video presentations of airships over London. The following year students failed to come to terms with the concept of utopia. Students almost all failed to be happy enough with life to be able to propose positive futures. It didn't help that the whole conference theme in 2009 was based around 'Creating a better world'. And here were students unable to create a better world and having a dystopian view of the future. The experience, although not directly related to the initial prompting two years previously, was still related to and developed from that initial future-gazing vision – in a negative way [21].

4.1.3 Agile methods and processes

A paper for the 2011 E&PDE conference was noted as it came for review [22]. This was a review of a set of methods used for developing software and not for product development or education – what are known as the Agile methods, developed from the Agile manifesto of as long ago as 2001 [23]. It appeared to be possible to run a trial on these methods almost immediately, getting some MSc students to utilise these for a simple design problem and to report back with a critique of the methods. This was carried out before the paper was finally presented at the 2011 conference. Contact was made with the paper's author, who readily agreed to produce a collaborative paper for the next conference in 2012 [24].

4.1.4 Pecha kuccha presentations

Another instance came from conversation with a conference attendee keen to promote a paper he was intending to present at the E&PDE conference that year. The paper proposed the use of pecha kucha presentations for assessing students [25]. These have a fixed format of using 20 Power Point slides, each of 20 seconds. This cuts down significantly on assessment time and still allows it to be carried out effectively. These presentations were used to assess on a very large module with upwards of 400 students, working in groups, and were effective for cutting down assessment time (about 100 students can be assessed in a morning, in groups). It also appears to increase the ability of staff to carry out an effective assessment [26]. The assessment process has been copied by others and is now part of the assessment toolkit of numerous academics.

5 CONCLUSIONS

These examples, though limited, demonstrate that conferences can be useful sources of ideas and of ways to take effective, frequently tested ideas and rooting them in other soil. If sufficient of this process takes place it can be an effective way for transmitting innovations and moving them from one place to another, developing, growing and changing the ideas as they travel. They can be one reasonably successful way that innovations started by individuals can be developed into cross-institution movements and become incorporated into the daily work of educators elsewhere. These, however, are only the tip of the iceberg. They are the examples of conscious copying that take place. What is underneath the iceberg is the bit that can't be seen – the subconscious copying, taking in ideas and attitudes in a natural manner that cannot by its very nature be seen or measured. Investigating this area is one for others to build on – leaving one with a tantalising glimpse of the real importance and effectiveness of conference attendance.

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TECHNOLOGY AND FORM — DESIGN RIGHTS VERSUS PATENTS

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ABSTRACT
Design innovations marketed by start-up companies are currently mostly protected through patents, which are tailored towards protecting scientific and measurable findings, and not suitable for harnessing product languages. Start-ups struggle with the costs needed for filing and protecting patents.
This paper relies on a comprehensive literature review and on interviews with key industry representatives and builds on a case study. The alleged infringement of the design rights related to the Trunki travel case will help assess the future impact of the current changes in the legislation.
This paper examines the differences and the potential connection points between patents and registered design rights. How do the benefits and disadvantages of patents compare to those of design registrations? How exactly can one extract value from both forms of intellectual property rights (IPR), and how can they be combined most effectively? The case studies will highlight other criteria for success such as access to complementary assets as defined by David Teece, and collaborative arrangements. Thus it will assess the future relevance of IPR within the wider context of innovation management and start-up business development.

Keywords: Innovation, management, intellectual property, start-up, business strategy, product language.

1 INTRODUCTION

According to The Oxford Handbook of Innovation Management 'Early work on the nature of innovation focused mostly on innovation driven by technical change' [1]. The authors argue that this 'focus on the generation and use of new scientific and technological knowledge' has 'created numerous blind spots for the research tradition' [2]. The 'blind spot' which this paper tackles, is the issue surrounding intellectual property rights (IPR) and the wide-spread negligence of the potential value of product languages in the context of design entrepreneurialism. Innovations marketed by start-up companies are currently mostly protected through patents, which are tailored towards protecting scientific and measurable findings, and not suitable for harnessing product languages. Start-ups also struggle with the costs involved in filing and protecting patents.
This paper compares patents to design rights to shed light into how these two forms of IPR can support proprietary design business development strategies. Following a brief literature review, which will help clarify subject-specific terms, a comparative case study will help to critically assess the efficacy of both protection mechanisms. To judge the benefits and disadvantages of patents and registered designs in relation to development priorities, the costs involved as well as the time it takes to secure these forms of IP, will be taken into consideration alongside their robustness. The case studies are based on qualitative semi-structured interviews. The bottom-up approach to data-collection in relation to the case studies is complimented through the review of online articles and press releases.

2 DEFINITIONS

2.1 Start-ups, appropriability and complementary assets

This study understands start-ups as micro companies that are led by one or several entrepreneurs. Spinouts are also often run by small teams, however, they are shielded by larger firms or institutions during the early development stages. What is to be noted here is the fact that start-ups are more vulnerable than spinouts, let alone established businesses, due to their lack in financial and technical resources, but also more flexible because their decision making is not hindered by complex rules and regulations as they are common within academic institutions and large corporations.

The position of start-ups differs from established businesses, partly because 'It may […] be harder for smaller businesses to select the right type of intellectual property protection, given the diversity of options available.' [3] At the same time start-ups rely on IPR to a larger extent than those companies who provide bespoke design services, because they are usually confronted with a weak appropriability regime at the outset.

The term "appropriability" was introduced by David J. Teece in 1986. It sums up 'the environmental factors… that govern an innovator's ability to capture the profits generated by an innovation.' [4] Due to competition and due to the possible need for collaborative arrangements such as outsourcing manufacturing, distribution, etc. the profits captured by a firm will always be below the theoretical optimum. The appropriability regime allows for the assessment of far from the theoretical optimum a company's profits will be. As the most important factors in relation to the appropriability regime, Teece lists 'the nature of the technology, and the efficacy of legal mechanisms of protection.' Teece argues that the degree to which returns can be appropriated from an innovation much depends on a company's access to complementary assets. These are resources needed to complete the value chain, for example manufacturing and materials, on the one hand, and distribution and sales on the other. Access to resources constitutes a challenge for start-ups, unless they evolve in an industry setting with existing access points. An innovator already established in the market may then be able to draw from existing business relations. Teece's appropriability theory suggests that IPR can strengthen a venture's appropriability regime, and thus compensate for the lack in access to complementary assets.

2.2 Patents and registered designs

At the same time Teece admits that patents can be of limited benefit in a lot of cases because 'Many patents can be "invented around" at modest cost.' [5] There are other possible pitfalls. Established businesses may simply infringe on IPR assuming that a small venture does not have the financial resources to defend their rights in court, or a competitor may challenge IPR. A patent is a probabilistic right, which means that it is only valid once it has been successfully defended in court. This raises the question to what extent patents may be more or less reliable than registered designs. Unregistered IPR, also known as informal IP, is more difficult to enforce than registered IP, because the latter provides evidence for what has been invented and when it has been invented. Patents are subjected to a novelty check and only granted if there is no prior art. But registered designs in the UK and Europe are not examined in relation to novelty. One could therefore argue that registered designs are more probabilistic than patents, although the novelty of latter can still be contested, even if granted.

The problem surrounding patents is that they are very expensive, and it takes a long time to process applications. Registered designs, on the other hand, can be secured within a matter of weeks and the fees required are only a fraction of those of patents. Start-ups need to develop fast in order to become viable. Thus patents are of limited value, whereas registered designs can be exploited almost instantly.

However there is another difficulty with the comparison between patents and design rights: They apply to different aspects of a novelty. To put it simply, the patent applies to the functional technical aspect. It describes what is required for an application to work. The registered design, on the other hand, applies to the shape of an artefact, regardless of the function, which it is to fulfil. The reason why the comparison between both means of protection is still important is because the designer entrepreneur can decide what and how to innovate during the inception period. In other words, a designer-entrepreneur can choose to innovate the form of an artefact, or its function, or both. Depending on this decision, different development and IP strategies will apply.

2.3 Product Language

The so-called Offenbach Theory, which was established by Jochen Gros in 1976-1987 and further discussed by Richard Fischer and Gerda Mikosch in 1984, defines the product function as the link between the product and the user. Dagmar Steffen reiterates this differentiation between practical functions and product languages / sensual functions [6]. The practical functions are what would be typically defined as part of a patent application, whereas the product language and sensual function are qualities implied in the visual design of a product, and thus can only be protected through design rights. But the product language as well as the sensual function can add value to the novelty, and they can be protected and promoted as key selling points. Faith in product languages is limited amongst designer-entrepreneurs, despite the fact that these aspects connect more closely with their academic education than the technology aspects of novelties. This lack of faith is evidenced in the comparably low number of filings of design registrations by comparison to patents. In 2009 only 2,111 designs were registered in the UK as opposed to 5,438 patents, which were filed [7]. One question to be discussed in this paper is whether or not embracing product languages as propagated by Verganti / Dell'Era may lead to new avenues of appropriating returns from innovations.

3 CASE STUDY: TRUNKI

We are left with the question why faith in design rights is limited. Tushnet from Georgetown University Law Center claims that 'The law's traditional bias against, even fear of, the visual may help explain why design patents [the US equivalent of registered design rights] have been of less interest to many intellectual property scholars than other bodies of IP law' [8]. The British government appears to have recognized people's reservations about investing in design rights, and a new law has been passed in the UK last year, which ought to turn registered designs into more effective means of protection: Clause 13 of the new IP Bill makes the deliberate infringement of registered design rights a criminal offence. The infringement of patents, on the other hand, remains subject to civil law. This is meant to encourage innovators to give more weight to design rights. The difficulty is, of course, to prove that infringement of rights is deliberate, and that the offender has acted knowingly. The other point that needs investigating is how close a design needs to be to a registered design to be considered an infringement. These and other questions will become clearer in the course of the following three case studies.

The Trunki case, which was invented by Rob Law during his undergraduate studies, took a comparatively long time to reach market. Trunki which can be seen on the left hand-side of Figure 5 is a travel case for children. Law's BBC Dragon's Den pitch failed but was followed shortly by an order of 400 units from John Lewis [19]. What exceeds public knowledge is the fact that the idea was incepted in 1997, almost 9 years before Trunki took centre stage on BBC television. Following his degree in product design at the University of Northumbria, Law worked for a number of design agencies in different countries. At the same time he continued developing the Trunki design, which was registered in 2003, and subsequently licensed out. Revenues remained within limits, which proves Clarysse / Kiefer's point that a licensing strategy alone is hardly ever sufficient for an entrepreneur at the outset [20]. However, the years of license provided Law with proof of market, which made it easier for him to take control over the Trunki trade. Rob Law pursued his endeavour without equity investment until 2009, when he secured £200K in order to expand his business [21]. Bootstrapping was at the core of his funding strategy, and some small loans in combination with support from family and friends helped to establish control over the business.

The Trunki travel case was first produced in China. Design patents in China, which are often seen as the equivalent to the European community registered design or the registered design in the UK, helped to fend off copycats who traded look-alike products locally. According to Law this has been time consuming but effective.

Trunki is a design-led initiative, and mainly protected through registered and unregistered design IP. The fact that Law managed to generate income from his design rights, proves that:

1. Designs can be licensed out, provided that they constitute codifiable knowledge, i.e. knowledge that can be articulated on paper, and secured exclusively.
2. Product languages and design rights can suffice to build successful SMEs around innovations

It has to be acknowledged that Trunki nowadays use a patented catch for their travel cases. This does not change the fact that the company was and remains design-led rather than tech-led. The patent gives the travel case a small technological advantage over competing products. Equally, if not to say more importantly, it allows the venture to benefit from the patent box. This is a law introduced in April 2013, which stipulates that companies receive a 50% reduction in corporation tax due on profits made of from its patented inventions. The combination of IPR is used to secure and control over the value chain.

In an interview, Rob Law confirmed that he could better focus on the business aspect, and limit his business development costs through by-passing patenting: 'We were able to survive the early days because we did not have a patent.' [22] Following the discontinuation of his licensing agreement in 2006, Law focused on complementary assets, namely the integration of production and the development of distribution networks. This means that the credibility of his business is not rooted in the formal IP, it is built on the proof of market, his access to complementary assets, and on his brand value which Law highlights as one of the most important assets. These credentials enabled him to secure £4m worth of equity investment in a second investment round in 2012. This makes it clear that a tech-led approach that utilizes patents is not the only way to pursue a design-entrepreneurial initiative.

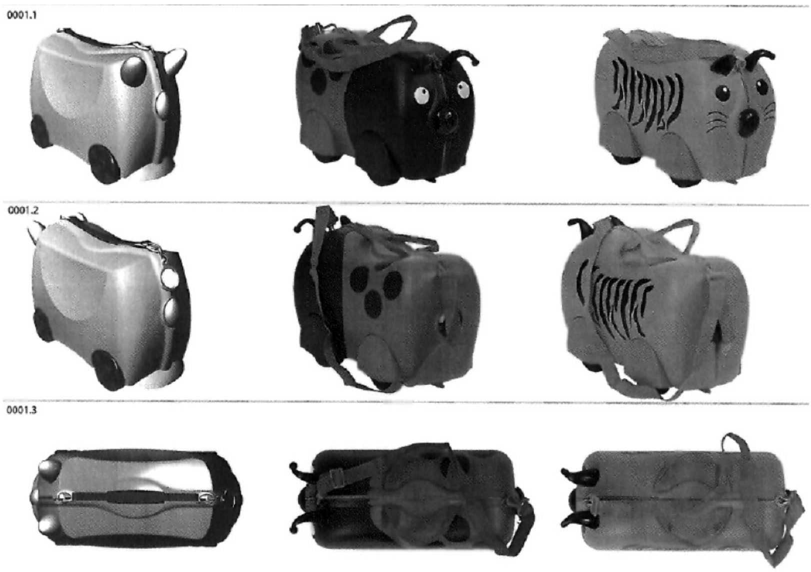

Figure 1. Trunki (left) versus Kiddie (middle and right)

Having established some clarity about the commercial value of design rights, the robustness of IP protection methods needs examining too. In November 2012, PMC International introduces the Kiddie travel case in the UK. This is a product the design of which bares close resemblance to Trunki. Rob Law's company Magmatic Ltd issues proceedings against PMC International in February 2013. The UK High Court rules in favour of Magmatic Ltd in June 2013. PMS International ensued an appeal, and the Court of Appeal found that the High Court judge had been wrong in ignoring the surface decoration of PMS' design, and in disregarding differenced in the shading of specific product components such as the wheels and the body of the cases. According to the Court of Appeal these details contributed to differences in the overall impression created by the designs. 'Had Magmatic avoided this colour distinction, as it could easily have done, then the point would not have arisen and the Court of Appeal may possibly have found in its favour.' [23]. Law, on the other hand, holds the view that alterations in the surface decoration ought not allow for infringing on the design rights that have been filed in relation to the shape of a product. The difficulty here is that the High Court of Appeal has judged based on an overall impression, which, according to Tushnet, is difficult to dissect [24].

4 CONCLUSION

There is growing criticism that intellectual property is not taught at design schools in the UK. But the challenge is far more wide-ranging. The appropriation of returns does not depend on IPR as much as designer-entrepreneurs often assume. Teece argues that IPR can compensate for the lack in complementary assets, and start-ups tend to have little access to the latter. Therefore it is understandable that designer-entrepreneurs focus first and foremost on IPR. However, this often delays the pursuit of access to complementary assets. The registered design is cost-effective and easy to obtain. Provided that an innovation lends itself to the use of registered design rights, a design-led development strategy can speed up the route to market by comparison to a technology-led approach. However, given that the threat of infringement is real, a registered design can only be seen as recommendable route if it is robust enough to fend off competitors. The outcome of the Trunki case will show how reliable an asset a registered design right is in the UK. The authorities seek to make sure that there is a possibility for competition in the field. However, the commercialization of product languages is currently underused by innovators due to a lack in confidence amongst both innovators and investors. Permitting a competing design to bypass design rights through minimal amendments will further compromise the designers' confidence in this form of IP.

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Chapter 14

Enterprise

FUTURE INDUSTRIAL DESIGN SPECIALISATIONS: A CENTRE FOR HIGH PERFORMANCE COMPOSITES

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ABSTRACT
This paper explores the potential to apply practice-led research findings to reforms in design education. Recent research in design for sports highlights the need for optimum use of contemporary materials, and the challenge of building new models of adaptive and resilient design practice is increasingly prominent. These new approaches are based on the use and knowledge of High Performance Composites (HPC), and how these materials may be used in future product design. A wide range of opportunities are possible, including product design for domestic settings, aged care, health services, people with disabilities and sporting markets.
Firstly, the paper describes improvements to Skeleton sleds for the Australian team competing in the 2014 Sochi Winter Olympic Games. The intense 4 month project consisted of two priority deliverables: Priority 1 was the design and fabrication of 5 pans to fit existing sled frames. Priority 2 involved the design and fabrication of 5 adjustable saddles and handles with a tailored individual insert for each specified athlete.
Secondly, the paper outlines the 16 month development of competitive Snowboard Cross bindings for an elite Olympic athlete. The paper outlines how learnings from the Skeleton and Snowboard binding projects are being catalysed as vehicles to create knowledge transfer tools and help build future design and manufacture applications in Australia. This addresses critical issues surrounding the fragmented approach to the design of High Performance Composites (HPC) products in identified markets. It also provides opportunities to better coordinate Industrial Design education, while improving research and fabrication knowledge transfer to undergraduates, postgraduates and researchers.

Keywords: Design education, design for sport, composites materials, industrial design.

1 INTRODUCTION

Economies like the Australian one continue to transition from being manufacturing based to service based [1]. In recent years in Australia there have been high level discussions and reports written [2] [3] where the need for Australia to adapt to these changes and to develop new and innovative ways of engaging the economy are paramount. Martin S puts this in context when he writes:
"Despite the announced demise of several high profile multi-nationals in Australia, manufacturing is not a dying industry. Provided policymakers focus on the right type of manufacturing, it has the potential to continue to be a significant contributor to our economy. However for this to occur, Australia's mindset about manufacturing must change. Australia cannot compete with low-cost, high-volume production. Our future is not in traditional assembly line production. It is in advanced manufacturing and opportunities in the global supply chain" [4]
Education specialisations need to be part of this change and university Industrial Design (ID) education is one of those key areas that can find and reflect these opportunities to aid and inform new endeavours. ID education has also been in a period of change both nationally[5] [6] and internationally [7] In Australia, for example, there is a mix of undergraduate and postgraduate ID course durations ranging from 3 to 4 years across the eleven universities offering industrial or product design courses. These may include embedded honours, plus 1 year honours program, and /or graduate programs. Consequently Industrial design course curricula have to deal with an ever widening scope of content relevant to ID.

1.1 Materials and Processes Selection

Materials and processes selection methods are integral to the education of ID professionals [8] [9]. It is therefore important to keep abreast with the ever expanding array of new materials and their applications, together with the advances in more traditional materials. In this environment, practicing design professionals can fall back on their existing, and perhaps limited, knowledge and experience of materials and not allow themselves to explore the possibilities of expanding their knowledge about, for example, composites materials. [10] [11] [12] Thus relying on their existing experiences with more traditional materials applications.

The authors and Centre for High Performance Composites are part of a new endeavour and opportunity to educate practicing designers as well as undergraduate and postgraduate students, expanding the pallet of materials and manufacturing processes available for selection, to include the use of composite materials (such as carbon fibre) beyond more traditional engineering-focused applications.

The two projects outlined below involved designing with and for high performance composite materials. These projects took a user centred approach and brought together designers and researches from ID at the University of Canberra (UC), and coaches, staff and athletes from the Australian Institute of Sport (AIS) and the Olympic Winter Institute (OWI) to optimise the design of Skeleton sleds for use at the 2014 Sochi Winter Olympic Games and snowboard bindings for future world cup events.

These projects exemplify a successful collaboration between the three organisations. This collaborative research culture and a focus on practice-led applied design research in areas such as sport aligns with the needs of the local community as well as national and international research and economic priorities.

2 PROJECTS

2.1 Skeleton Project

The Sochi Olympic Skeleton project consisted of two priority deliverables: Priority 1 was the design and fabrication of 5 pans to fit existing sled frames. Priority 2 involved the design and fabrication of 5 adjustable saddles and handles with a tailored individual insert for each selected athlete.

Our approach throughout the project was to research, design and manufacture elements for the skeleton sled with and for the skeleton coaches and athletes.

We first undertook scoping research to inform the design process and establish defined design criteria. Once these criteria were defined, we began the process of applying them to the design and manufacture process. This process was iterative, with coaches and athletes being an integral part of the design approach. They provided feedback and information at key stages of design, development and manufacture. The subsequent designs, prototypes and final working elements of the new revised Skeleton sled components were successfully completed and handed over to the AIS staff in late September 2013.

2.1.1 Priority 1: Sled Pans

The sled pans (the smooth under tray that encases the steel subfame) were developed incorporating engineering recommendations [13] regarding the possible aerodynamic advantage of lengthening the pan to the maximum allowable length of 1200mm. The design also maintained compliance with Subclause 14.6 of the FIBT Skeleton rules. Subsequently, perimeter inserts were also designed and installed to each pan. The design phase determined the exact configuration and dimensions of the pan, materials for use and manufacturing methods.

The manufacturing phase included production of the tooling components (a master pattern and a composite master mould), and 5 identical prototype pans. Additional work included design, manufacture and installation of perimeter inserts to each pan to allow for the effective and efficient attachment of the aerodynamic rubber covers.

2.1.2 Priority 2: Sled Saddles

Priority 2 involved the design and making of 5 new removable saddles (the frame that cradles the athlete in place and incorporates handle to push with at start) to suit the 5 specified individual athlete's anthropometrics, function, usability and comfort. The saddle redesign also aimed to address vibration dampening and control enhancement via individual removable inserts tailored to each athlete but using the same saddle components and base sled. Human ethics approval was received from AIS ethics committee before commencing this stage of the project.

The design and manufacture of the saddles was firstly approached by interviewing the athletes and coaches about their needs, wants and opinions about existing and possible future saddle set-ups. Individual anthropometric sizing was achieved via taking a cast of each athlete's torso, using a vacuum bag of polystyrene beads to replicate the form around the athlete. This form was then used to cast a plaster of Paris impression of each athlete. Individual plaster shells were used as molds for the individual composite saddle inserts. (see Fig.1) The saddle and handle components for 5 sleds were designed, then cut and folded from stainless steel to agreed specifications. After the on-time delivery of the new sled pans and saddles, testing was conducted in the lead-up to Sochi Winter Olympics at various World Cup and training sessions.

Figure 1. Selected Skeleton Sled development process [14]

The lead-up events in North America and in Europe showed the potential of new sleds. Michelle Steele claimed 3rd place in Calgary and 4th place in Konigssee. Another of the athletes, Lucy Chaffer, recorded top 10 finishes in the first two World Cup events and John Farrow obtained a 12th at St Moritz and 20th at Calgary. As stated in a specialized magazine [15] *"The sleds are more comfortable and the athletes are more confident going into a race knowing the shells have been designed specifically for them. We're very thankful to the University of Canberra for their help and we couldn't be happier with the collaboration," he says. "We had great feedback from the athletes and the coaching staff," AIS senior physiologist and skeleton program manager Dale Chapman says. "The testing we had done on the sleds found the shape and design was faster than the commercial product." Dr Chapman says the scrutineers of the sleds were also impressed with the changes made."*

2.2 Snowboard Binding Project

The authors were approached simultaneously to design and make a set of custom-made bindings for Alex "Chumpy" Pullin, Australian world champion and an elite athlete in Snowboard Cross. The need for a new binding emerged from the lack of commercially available binding suitable for Snowboard Cross competitions. The problem with existing commercial bindings is that they are unable to withstand the repeated loads generated by elite snowboard cross athletes competing at world cup level. These loads eventually result in failures which render the bindings unusable and unrepairable. Often these breakages occur on a new binding after only one run.

2.2.1 Design requirements

As a custom product, it was agreed that the design of the new binding would employ materials and manufacturing processes suitable for low-volume production. The primary aim of the project was to develop a custom-made binding with superior mechanical properties, as compared to the commercially-available bindings currently used by Alex Pullin. As such, the current bindings would be used as a benchmark to compare the new binding against. The design criteria for the new binding was that it needed:

- To have improved strength in areas where the benchmark binding was known to fail.
- To have the same stiffness characteristics as that of the benchmark binding.
- To have exactly the same ergonomics as the benchmark binding.
- Its weight to be similar or lighter than that of the benchmark binding.
- To use the same "off-the-shelf" buckles, straps and fittings as used in the benchmark binding.
- To be able to be made on request.

- Its aesthetics to be as close as possible to those of the benchmark binding.

For this project, 3 priorities were identified which included:

1. Research, design and making: of a low-volume production run of custom Snowboard bindings specifically for Alex Pullin. This would also involve the appropriate selection of materials and fabrication methods.
2. Testing: physical stiffness testing in the lab and Finite Element Analysis (FEA) of the new binding to be performed by UC-ID. Physical, "on-the-snow" testing to be conducted by the AIS and the OWI, with feedback forwarded to UC-ID.
3. Further research: conducted in collaboration with the OWI and AIS to develop a binding suitable for all athletes in the Australian Snowboard Cross team. The design would be based on knowledge gained from the custom binding designed in priorities 1-2

2.2.2 Methodology

Using the benchmark binding as a template to design the new custom Snowboard cross bindings, we aimed to satisfy the design requirements (improved strength without increasing stiffness or weight relative to the benchmark binding). The materials chosen for the new binding were High Performance Composites (HPC). The process for designing and manufacturing the binding was divided into five stages, which included task clarification**,** design, manufacture, testing and documentation.

This process led to the design, manufacture and testing of three sets of HPC prototype bindings. HPC prototype bindings 1 and 2 were constructed with a dual carbon shell base and a dual Kevlar shell high-back, as seen in figure 2. However, workshop tests revealed that both the bases and high-backs were too stiff compared to the benchmark binding. Prototype binding 2 was constructed with a single Kevlar shell base (made from the same molds used to make the inner base shell of prototype bindings 1 and 2) and a high-back with a Kevlar inner shell and a Rapid Prototyped (RP) nylon outer shell as seen in figure 2 'left'. Prototype binding 2 passed all lab tests with almost identical bending and flex characteristics to those of the benchmark binding. This was followed with 6 weeks of extensive and successful "on-snow" testing by Alex Pullin, who was completely satisfied with the binding's performance. Consequently, this lead to the OWI and AIS to request a further 3 pairs of HPC bindings, identical to HPC prototype binding 2 for Alex Pullin to compete in the 2015 snowboard cross world cup races. Following the design process outlined earlier, 3 new snowboard cross HPC competition bindings were made and delivered on time and budget (see figure 2 'right').

Figure 2. Prototype bindings above left and competition bindings above right

3 DISCUSSION AND CONCLUSIONS

3.1 Designing our Composites Future

At the level of educational policy, industrial design graduates and current practitioners need to be equipped with skill sets appropriate to the challenges facing the Australian economy. Thus, knowledge gained from these projects is also valuable for developing new curricula to teach design and manufacture of products made from HPC materials. Currently, much of the knowledge and applications regarding HPC materials is associated with engineering and very little applies to design of consumer products. This was evidenced by a literature review on composite design which mostly found papers and books associated with engineering.

An important outcome from these two projects is a valuable photographic record of every step of the process. This record is invaluable as a research reference and exemplar for student education. Therefore it is through projects like these where knowledge, processes (as listed earlier), requirements and opportunities applicable to consumer products can be acquired. Based on experience gained in these projects, we propose 5 main requirements an educational institution needs to consider when conducting research, design and development of HPC consumer products. These include 1) User Centred Approach) 2) HPC expertise, 3) Design expertise, 4) Computer Aided Design and Drafting (CADD) expertise, 5) Access to RP, CNC machining, Laser cutting and sheet metal fabrication, 6) Workshop facility.

3.1.1 User centred approach

A user centered approach is critical in the development of products and services. In the two cases outlined above access to the athletes and coaches was critical in the successful development of the end products.

3.1.2 High Performance Composites (HPC) Expertise

To design and develop HPC products, an important requirement is access to expertise in the design and manufacture of HPC products. At the University of Canberra this expertise resides in house with one staff member having had a composite design and manufacturing business for over 10 years. However, we also source and share knowledge with external enterprises with expertise in this area, some of which we have collaborated with on the design of HPC projects.

3.1.3 Design Expertise

The designer is central to the project, not only at the design stage but also planning and coordinating all the resources in order to complete the project. A further requirement is to have at least one designer with CADD expertise. This is important because most consumer products, such as the HPC snowboard cross binding, require numerous parts to fit together with close tolerances; this is straight forward with CADD. A CADD model also enabled numerous Computer Aided Manufacturing (CAM) possibilities such as plastic RP parts (for verification and as patterns), metal RP dies, laser cutting, sheet metal manufacturing etc.

3.1.4 Computer Aided Design and Drafting (CADD) software, hardware and expertise

The advantages of CADD are primarily for design verification. These include checking fits and tolerances (as previously mentioned), checking articulation of parts, aesthetics and finite element analysis to check for structural integrity**.**

CADD software suitable for modelling HPC products ideally requires the following, 1) ability to contain numerous part files within an assembly file, 2) surface modelling capabilities to allow the construction of complex, double curvature surfaces which are common in HPC parts/products, 3) solid modelling, combined with surface modelling to make 3D modelling easier and faster and 4) analysis tools to check dimensions, fits and tolerances, including Finite Element Analysis (FEA). The following CADD software is commonly used for product design and is also ideal for HPC product design: CREO, Solidworks, SolidEdge, Catia and Unigraphics

3.1.5 Manufacturing Processes

Processes that combine with CADD, such as various forms of Rapid Prototyping (RP), CNC machining, Laser cutting and sheet metal fabrication are all ideal. Because they are digitally controlled, taking data directly from CADD, they provide design verification and fast turnaround times with very high precision at reasonably low costs. This is especially the case where research, design and development requiring prototyping and low-volume production are required. This applies whether these processes are available in-house, or sourced externally.

3.1.6 Fabrication and Testing Facility (Fab Lab)

A Fab Lab enables prototyping, manufacturing, assembly and testing. [16] Although final manufacturing and assembly can be performed externally, the initial research and development is best conducted in- house. Therefore, the Fab Lab is essential for prototyping and refining, prototype testing (making testing jigs) and testing of final assembled products (for quality control purposes). Equipment recommended for making HPC parts include: Weighing scales accurate to 0.01 grams for mixing resigns, an oven to cure HPC, a freezer to store HPC materials, a vacuum machine for vacuum molding HPC parts, a laser cutter, plus typical workshop equipment such as a disc sander, milling machine, lathe, hand drill, drill press and general workshop mechanical and electrical hand tools.

4 DESIGN EDUCATION SPECIALISATIONS

As part of strategic alignment with local and national government priorities, the University of Canberra Centre for High Performance Composites is designed to deliver innovative design-led research outputs, PhD and Honours graduates and educational outcomes which explore the applications of HPC materials in small-scale manufacturing. Although in the early stages of development ,knowledge is being developed to further apply to emerging markets such as design for the ageing, well-being, recreational sport, health and disability. Local links with health and sports institutions are facilitating the applicability of the Centre's multidisciplinary projects, the educational program will ensure that new knowledge is developed and disseminated among the next generation of design professionals. Current collaborative research with other organisations will benefit from increased capacity and knowledge transfer. Industrial design graduates and current practitioners need to be equipped with skill sets appropriate to the challenges facing the Australian economy.

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DEVELOPING RESEARCH INFORMED PRODUCT DESIGN RESOURCES TO SUPPORT TEACHING AND LEARNING IN THE USE OF SKETCHES, DRAWINGS, MODELS AND PROTOTOYPES

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ABSTRACT
The use of sketches, drawings, models and prototypes lie at the heart of teaching and learning in product/industrial design education. Whilst numerous text books are available to support the development of technique, particularly in sketching and drawing, their contextualisation within the product development process remains problematic. This paper presents three case studies in which academic research in the use of design representations was translated into open access resources through print production, video, web, app and PDF download. The areas of research focused on the impact of emerging technologies and supporting communication/understanding through the use of design representations. The case studies discuss Digital Industrial Design (a web-based resource for entirely digital modelling methods); CoLab (a designer/engineer web-based collaboration tool); and iD Cards (a tool to support communication and understanding using a graphic design solution embedded as an iPhone/Android app, pdf download, physical cards, video). The paper concludes that whilst considerable effort may be required to translate academic research into resources for the educator community, this step performs an essential role in terms of access, validation and impact.

Keywords: Case studies, sketches, drawings, models, prototypes.

1 INTRODUCTION

As the number of design-related journals reaches an all-time high, it is timely to reflect on ways in which relevant findings from research might be made available to design students. This paper reports on strategies to translate findings published in academic journal papers into open access resources that support learning and teaching in the use of sketches, drawings, models and prototypes. These resources focus on digital design methods (Digital Industrial Design); collaboration between industrial designers and engineering designers (CoLab); and communication during new product development (iD Cards).

2 DIGITAL INDUSTRIAL DESIGN (DID) – A WEB-BASED RESOURCE FOR ENTIRELY DIGITAL MODELLING METHODS

Incremental growth has resulted in a wide variety of digital tools that have the capacity to impact on the activities associated with professional industrial and product design practice [1,2]; thereby, “enabling designers and engineers to explore and push the limits of product form and visual complexity, to evaluate better and to test more accurately” [3]. Despite this capability and the ambitious claims of software and hardware developers, professional practice in industrial and product design continues to be undertaken using a hybrid approach that integrates both digital and non-digital techniques [1,4]. One of the reasons for this is that the commercial constraints of professional practice necessitate the use of proven techniques when working in a commercial context. This can result in resistance to change due to the risk posed if design solutions fail to be delivered on time and to specification [5]. In contrast, academic research that employs design activity is not constrained by a client/practitioner relationship and has the potential to make a significant contribution to issues relating to practice that cannot readily be explored in a commercial environment. This approach fits within what can be referred to as ‘practice-led research’ in which, “the professional and/or creative practices of art, design or architecture play an instrumental part in the inquiry” [6]. Archer [7] identifies this as, “research through art and design which, for certain research questions, is the most appropriate approach to data collection”.

A key contribution of academic research to design practice is in the impartial evaluation of new methods and approaches that have the potential to disrupt existing practice and identify opportunities for paradigm shift. The competitive and closed nature of professional practice also means that it has a natural tendency to evolve without open reflection and academic research can make a significant contribution to exploring the potential for change.

Academic research has a history of reporting on the emergence of individual design technologies and their potential to impact on practice. There is therefore an inherent value in the contextualisation of activities that must be undertaken before and after the proposed intervention to avoid exposure of a partial picture. To fully contextualise and build on stand-alone studies that have partially explored the role and contribution of digital methods to professional practice, this paper reports on a research project to investigate the potential for a complete model of practice in which all core activities of industrial design are undertaken using only digital methods. It is acknowledged that this represents a somewhat provocative approach as opinion is divided on the capacity of digital methods to replace established non-digital techniques. In developing the methodology for the study, the research sought to answer what digital tools and methods are available to replicate those of non-digital industrial design practice; how should digital tools and methods be employed to support an entirely digital approach to industrial design; and what are the key issues arising from the implementation of an entirely digital approach to industrial design?

Having developed a theoretical methodological approach, this was used as the basis for a complete industrial design case study that explored the potential to operate entirely digitally using two contrasting stylistic directions (Geometric and Organic). This included the use of a haptic feedback device to emulate workshop-based sketch modelling and the production of a full colour low fidelity appearance model as an alternative to a fabricated/painted appearance model. The process resulted in the production of significant material arising from the DID phases. The DID approach plus the designed outcomes were considered to be of value to students, educators, practitioners and researchers which led to a web-based tool being developed to demonstrate the process and outcomes. This included the phases of DID in the context of Concept Generation, Design Development and Specification; thumbnail images of the designed outputs that could be enlarged for greater clarity; and a brief overview of the project. The three phases of DID with thumbnail images of the designed outcomes can be seen in Figure 1.

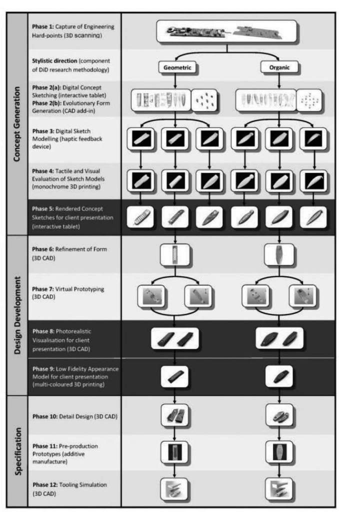

Figure 1. Interactive web-based dissemination tool

The DID approach to product development is available on an open access website at www.lboro.ac.uk/microsites/lds/did/ with a full record of the project accepted for academic publication in 2015 in the International Journal of Product Development as a paper titled "Digital sketching and haptic sketch modelling during product design and development".

3 COLAB – A DESIGNER/ENGINEER WEB-BASED COLLABORATION TOOL

Effective communication is essential when undertaking new product development and Clark and Wheelwright [8] note the importance of this in achieving cohesion and efficiency. Studies indicate that engineering designers struggle to fully understand the vocabulary used by industrial designers but, in contrast, Fiske [9] identifies that industrial designers find it difficult to understand engineering design-related issues such as technical specifications. In addition, words may not have the same meaning for all members of a design team, with Persson and Warell [10] acknowledging that communication becomes more effective once the team develops a common vocabulary through and understanding of communicative codes and language, e.g. symbols, product reproductions and message content. Erhorn and Stark [11] note that because the various participants in new product development have their own vocabulary that is suited to specific activities, there can be difficulty in communicating and understanding amongst those outside the specific professional group. Although the language may be similar, identical words have been found to have different meanings [12].

The issue of communication between industrial designers and engineering designers was undertaken through PhD research supervised by the author that involved an empirical study to identify and resolve barriers to effective collaborative [13]. Following the literature review, data collection commenced with a ten week study with 17 design consultancies specialising in electronic consumer products. The subjects were qualified industrial designers and engineering designers with varying levels of experience. The fieldwork consisted of 45 hours of in-depth interviews and 80 hours of observations. The empirical studies utilised a qualitative research methodology, incorporating semi-structured interviews and the observation of participants during a commercial project. The interviews allowed respondents to fully describe their personal experiences relating to group interaction, reasons for project success and failure and methods used during the project. To increase reliability, a mix of large, medium and small companies with an equal number of industrial designers and engineering designers participated in the survey. The data was coded into a spreadsheet which identified 61 problem categories. A coding and clustering technique was then used to condense the results into a matrix using recurrence and importance.

The matrix highlighted the 19 most frequently occurring problems that occurred three or more times which were then categorised into three groups. Conflict in values and principles identified that engineering designers tended to work with quantified solutions with a focus on efficiency whereas industrial designers favoured an open-ended approach with less constrained solutions. Differences in design representation identified that a lack of a common understanding/ language represented a significant obstacle to effective collaboration. Educational differences identified that dissimilar education resulted in different capabilities, approaches and expectations

Observations were used to obtain detailed information during a 2 week case study that involved the commercial design of an electronic communication device that required collaboration between industrial designers and engineering designers within a design consultancy. Analysis of the results identified that a lack of a common language in design representations made it more difficult for industrial designers and engineering designers to understand and empathise with each other.

The potentially ill-defined nature of sketches can lead to them being interpreted differently by industrial designers and engineering designers, but this ambiguity also enables industrial designers to re-interpret them and gain new insights [14]. While engineering designers employ formal systems, such as ISO standards, industrial designers have been cited as using less established representation types and ones that are ill-defined and imprecise [15]. In highlighting the differences in the vocabulary of each discipline, Smith [16] suggests the use of a common understanding of shared definitions.

In developing a tool to promote shared understanding, the PhD research sought to provide definitions for the key design representations used by industrial designers and engineering designers; when they were used; and to identify the key types of design and technical information that they were used to communicate. Numerous formats for the emerging tool were evaluated and a physical card format was selected on the basis of portability and convenience.

The cards were developed as sets of red cards for industrial designers and blue cards for engineering designers, with the content for each set being divided into three sections. The red and blue sets differed in the fact that the popularity of use for the design representations was not the same for industrial designers and engineering designers as evident through the data on use that was collected via interviews. Section one of the cards identifies the key design stages of the new product development process (concept design, design development, embodiment design, specification). The front face provides a definition of a specific design stage, with four cards being used to indicate the popularity of use of representations during each of four stages with the most popular appearing at the top. Section two describes the key design and technical information used by industrial designers and engineering designers in the design process. The front face has a definition of the type of design or technical information, with the reverse showing the popularity of specific representations to communicate the design or technical information. Section three identifies the 34 most significant design representations used by industrial designers and engineering designers during the design process. The front face gives a definition of the design representation and the reverse face shows the design/technical information that is embodied in the representation plus the popularity of the representation when used during a specific design stage. The card-based tool, called "CoLab", was validated through semi-structured interviews with participants from 15 design companies and academic institutions. The results indicated that respondents felt that the tool would provide a common ground in design representations and contribute to enhanced collaboration.

Whilst the CoLab cards had a positive impact on collaboration, the cost of printing the 114 full-colour, double sided cards proved to be a barrier to commercialisation. However, having acknowledged their positive contribution, funding was received from the Royal Academy of Engineering to translate the tool into a free website. Figure 2 shows the web page for the Study Sketch where clicking on the words that describe the information that it is used to communicate opens up a new page for that specific information. This is also the case with the words for the design stages.

Figure 2. Study Sketch screen from the CoLab web site

The CoLab tool to support collaboration and communication between industrial designers and engineering designers is available on an open access website at www.colab.lboro.ac.uk with a full record of the project available as an academic publication in the Design Journal [17].

4 ID CARDS – A TOOL TO SUPPORT COMMUNICATION AND UNDERSTANDING DURING PRODUCT DEVELOPMENT

Results from Pei's PhD gave an overwhelmingly positive response to the concept of a design tool to support collaboration and communication being produced in a physical. During a search for more economical alternatives to a playing card-type product as proposed in the original PhD, the commercially available 'Z-Card' fold-out printing format was identified as a potential solution as it was available in a variety of sizes and aspect ratios. Although the Z-Card product was cost effective, the format was not suitable for the creation of 114 double-sided as used on the CoLab tool.

During a review of the potential for the Z-Card format to be used as an alternative to the 114 double-sided cards, considerable interest in the CoLab tool was demonstrated by the Industrial Designers Society of America (IDSA) after presentation at their International Conference. Its contribution in supporting student and novice designers was particularly well received. Ensuing discussions resulted agreement to produce an IDSA/Loughborough University branded design tool that included the full range of design representations used by industrial designers (when they were used and for what types of information). Significant development work was undertaken by the author to redesign the CoLab tool for the Z-Card format which was re-branded iD Cards. The iD Cards had credit card-size front and rear covers that were printed on gloss card, with the fold-out panels being on paper. Yellow tabs indicated at which stage of product development the design representations were used, with tabs to indicate if they were generally used to communicate design information (red tabs) or engineering information (blue tabs). The two sides of the folded-out iD Cards can be seen in Figure 3.

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ABSTRACT
This paper explores the potential to apply practice-led research findings to reforms in design education. Recent research in design for sports highlights the need for optimum use of contemporary materials, and the challenge of building new models of adaptive and resilient design practice is increasingly prominent. These new approaches are based on the use and knowledge of High Performance Composites (HPC), and how these materials may be used in future product design. A wide range of opportunities are possible, including product design for domestic settings, aged care, health services, people with disabilities and sporting markets.
Firstly, the paper describes improvements to Skeleton sleds for the Australian team competing in the 2014 Sochi Winter Olympic Games. The intense 4 month project consisted of two priority deliverables: Priority 1 was the design and fabrication of 5 pans to fit existing sled frames. Priority 2

Figure 3. Both sides of folded-out iD Cards

The collaboration with the Industrial Designers Society of America (IDSA) facilitated the printing and distribution of the iD Cards in the UK and USA, with the potential to access a modified PDF via a link on the web site for the Design Practice Research Group at Loughborough University (www.lboro.ac.uk/departments/lds/research/groups/design-practice/). Five thousand of the iD Cards were distributed to students and practitioner members of the IDSA in April 2011 and they were selected as a finalist in the 2011 International Design Excellence Awards (IDEA).
In response to on-going demand for the iD Cards, a PDF version was launched on the web site of the Design Practice Research Group at Loughborough University and, in 2013, funding was made available by the Higher Education Funding Council for England to translate the iD Cards into a smartphone app. Following an interaction design exercise by the author, the iD Cards app was launched as a free download from iTunes and Google Play in January 2014. By October 2014, there had been 4000 downloads and 1460 views of the supporting video (www.youtube.com/watch?v=ZgvjhywMSwY&feature=youtu.be.) Figure 4 shows the app being used to compare the capabilities of design representations.

Figure 4. iD Cards Android and iPhone app

5 CONCLUSIONS

To maximize the potential for outcomes from academic research to become accessible and valued by students/educators, three approaches emerge from the presented case studies. To avoid unexpected expense and delay, the first involves the need to integrate a strategy for appropriate dissemination within the research methodology. This also ensures that all required materials are rigorously collected throughout the research process in preparation for the creation of the resource. The second is to acknowledge that resources for student designers must have qualities that are appropriate for a visually literate profession. For those developed by researchers who are themselves designers, this is a relatively straightforward process as they can, in effect, undertake the design activity themselves. In fact, the author believes that researchers with backgrounds as competent design practitioners are in an advantageous position in this respect due to their in-depth knowledge of the research for which they are responsible and capacity to identify opportunities as they emerge. Without an embedded design capability, professional design services would be required with associated funding implications. Thirdly, it is difficult to make claims for the relevance and impact of a resource without evidence. Collaboration and validation with professional associations or substantial groups of students/designers can make this process relatively straightforward providing, of course, that the resource meets their needs. Related to relevance and impact is the advantage of employing digital resources that allow view/downloads to be recorded. This then becomes a useful metric when reporting on the significance of the work to the academic community.

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EXPLORING THE POTENTIAL OF ENQUIRY-BASED LEARNING IN A PROCESS MODELLING COURSE

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ABSTRACT
Nowadays engineers have to have multi-skills to cope with the fierce competition of the work environment. Successful engineers must not only have the technical proficiency but also must have the ability to effectively express their knowledge through a wide variety of personal skills such as presentation, management and communication skills. The influence of Enquiry Based Learning (EBL) on student performance was an interesting topic by many researchers and has been identified as an important learning approach to improve team-building, collaboration, communication skills for engineering students. The aim of this paper is to study the potential that EBL holds to improve student engagement and professional skills and hence improve their academic performance. An active learning process-modelling course had been achieved using EBL. The technique had been used to improve the practical skills of engineering students. Despite differences in the student's background, necessary practical skills were shared and EBL delivered a robust method to emerge these skills into the study program.

Keywords: EBL, engineering, process modelling.

1 INTRODUCTION

Students at higher education institutes are diverse in many aspects, e.g. combination of different cultures, different backgrounds and different secondary schools. Consequently, students are expected to have different learning styles. For example, some students prefer to learn by listening while some others learn better by reading. Some students like to watch a presentation or an animation and some others prefer to do hand-on activities. Additionally, although researchers recommend engaging students in active and deep learning environment, it is not always the case that classes retain their activity as student engagement becomes more challenging when teaching to a mixed group of national and overseas students. Consequently, students are expected to have different learning styles while lecturers are expected adapt their classes to meet the needs of the auditory, visual, and tactile-kinaesthetic learners [1].

Enquiry-Based Learning EBL is an interesting teaching approach in which learning is triggered and stimulated by enquiry. Knowledge construction and deep understanding of concepts are the main characteristics of EBL approach. Additionally, skills development, share responsibility and critical thinking are the most common learning outcomes of EBL. EBL is any process of search and learning through enquiry, in which learning is self-directed and driven by learners. EBL has been a strategic learning approach at many universities over the past few years and it has been implemented in many disciplines. EBL is commonly used as a teaching approach in engineering, geography and medical programs. Applying this approach develops a wide range of abilities and skills such as, knowledge creation, communication skills, team working skills, management skills and problem-solving skills [2, 3]. These skills are highly appreciated by employers. The first step in EBL is to encourage individuals to share responsibilities for learning [4]. This improves independent learning, team working skills and helps to stop the "spoon-feeding" learning of some students.

The influence of EBL on student performance was an interesting point for many researchers over the past 15 years. Palmer et al. examined EBL as a method of delivery through student-led seminars as part of the assessment [5]. The aim was to maximize student academic performance. Significant impact on students' grades was recorded. Ashby et al. reported the impact of using EBL approach on health and nursing lectures. The results showed two different views regarding the capability of EBL Unlike teachers, students were excited by the approach. Teachers felt discourage and were not sure if implementation EBL was really helpful or not [6]. Powell attempted to implement EBL in third year Electrical and Electronic Engineering module. In that module, students were asked to think about the manufacturing techniques and requirements of high definition television [7]. The enquiry was triggered through the discussion of current and future TV technologies. The results indicated that EBL helped students to engage more and learn about broad range of topics. One year later, the same author used EBL-based project to develop student skills in three main areas that include team working, project planning and group presentation. The results showed that students realized good improvements in their team working skills, presentation skill and become more confident [8]. Spronken-Smith and Walker tested three cases of enquiries, named as, "structured enquiry", "guided enquiry" and "open enquiry" to examine how enquiry-based learning can strength teaching-research relationship [9]. In structured enquiry, teachers provide a problem to students as well as a plan to solve it. Guided enquiry means teachers provide a problem to encourage enquiry but students have to explore this problem themselves. If students have the opportunity to choose a problem themselves as well as explore possible solutions of this problem through the full enquiry cycle that would be called open enquiry. The findings indicated that EBL can improve the relationship between teaching and research when modules are designed using open enquiry approach. This relationship can be even better if teacher is a co-learner in the process.

Students engagement can be defined as an active participation of students in lectures on specific topic. Student engagement is one of the major issues in education and has been a subject of investigation for many years. Academics have proposed several ideas to address this issue. Approaches that make learning is more challenging for students as well as inspirational are possible solution [10]. When students are actively engaged, they participate more during lectures and can achieve deeper understanding of concepts. Davies investigated the influence of using numerical simulation of heat transfer in Mechanical Engineering module as a teaching tool on student engagement [11]. In this module, the first five lectures were used to introduce the theoretical background and the remaining weeks were used for simulation. The response was measured through module questionnaire before, during and after the teaching period in addition to informal discussion after the teaching period. The results indicated that student engagement did not depend on the simulation software only but the whole learning environment. Also it was crucial to allow enough time for students to engage which itself can be considered as a learning outcome. Very similar conclusion was also reported by Davies [11]. It was also reported that simulation shouldn't be used to replicate a scenario instead it should be used as a design too keeping learning as the main tool. Thus the simulation must be consistent with the learning outcomes and objectives. Higher engagement was found at higher-level classes, in classes with small number of students and when problem-based learning approach was used by [12]. Social media were also used to support student engagement. Cole studied the use of WiKi technology to promote student engagement [13]. Willmot investigated the use of digital video production as a novel technique of reporting project work [10]. The study was performed on students from two UK institutions and several disciplines that include engineering. In general, these technologies showed good potential in increasing student motivation and engagement.

Can EBL improve student engagement along with the academic performance? The answer is YES. Summerlee and Murray studied the impact of EBL on student engagement, confidence and academic performance [14]. The study provides quantitative results that validate previous qualitative findings reported by the same authors. The study compared two groups of first year students undertaken same module. The module was delivered to the first group using EBL approach and to the second group using traditional lectures. The obtained results were in the form of survey data and showed a significant improvement in the academic performance of the EBL group compared with the second group. The EBL group used more advanced resources to complete research assignments. Additionally, higher level of engagement was reported by the EBL students which had a very positive impact on their confidence.

Engineering is an applying area that depends on critical thinking, applying science, and problems solving. While the majority of undergraduate engineering modules are taught through classical lectures, applying EBL method can give students an opportunity to improve interaction with lecturer and critical thinking skills through class activities especially with fastpaced modules that in many cases end up with a low amount of student engagement. The aim of this research to overcome difficulties accompanied with diverse students' background. Here, it is planned to use EBL in teaching of a modelling module for undergraduate engineering students. The objective here is to improve students engagement and academic performance of students comes from diverse background.

2 METHODOLOGY

Process Modelling is a 10-credit optional module for 4th year undergraduate students while it is compulsory module for all MSc students from the new AME master program. The enrolment of the 4th year students is 13 and of MSc students are 17 for the (academic year 2013/2014). The majority of the 4th year students are from the School of Mechanical Engineering and the rest are from the School of Metallurgy and Materials. The MSc students are studying at the University of Birmingham for the first time and the majority of them are overseas. It can be easily recognized how mix that group of students is from such diverse aspects. The module establishes the basic concepts of numerical methods for instance Finite Difference (FD), Finite Volume (FV) and Finite Elements (FE). The module covers other topics such as the relationship between the physics of processes and process parameters and defect predictions. The aim of the module is to expose the students to the practical aspects of process modelling using proprietary modelling software.

It was aimed to get the practical experience through this course and the students were expected to complete an assignment which involves modelling of real manufacturing process and impose design changes to improve a product taking into consideration the cost implications. The module had been divided into three stages. The first stage was four lectures, 2 hours each, where the theoretical background of Finite Difference, Finite Volume and Finite Element methods were introduced. The second stage was two hours lecture where an invited speaker from industry explained to students how these numerical tools were used in the real life i.e. industry. The last stage was 10 hours of computer labs over five consecutive weeks where EBL was also implemented. The aim of this stage was to guide students to learn how to use numerical simulation software to model, simulate and understand an actual manufacturing process. Very similar approach was used before in Mechanical Engineering discipline [11]. At this stage, students were divided into small groups and each group undertook a different manufacturing process. In fact, the use of numerical simulation to support student engagement had shown very good results [11]. According to the literature review shown above, the implementation EBL approach in such high-level module with such small number of students would improve student academic performance and develop important academic skills along with high-level of engagement and confidence [12].

In the first session, the lecturer clearly explained the learning outcomes and his strategy to deliver the module. He also explained to students their role and what was expected from them [15]. As mentioned above, the number of students who registered in this module is 30. According to literature, four to six is the right number of students for small group teaching [16]. Therefore students are divided into 6 groups 5 students each. The most effective case of EBL is when students have the opportunity to choose problem themselves as well as explore possible solutions of this problem through the full enquiry cycle, defined as "Open Enquiry" [9]. Therefore at the beginning of the module the lecturer asked each group to choose a manufacturing process. Over the first four weeks, the lecturer introduced the concept of numerical approximation and the steps of numerical modelling. The lecturer used different teaching aids to explain the theoretical background of FD, FV and FV. The teaching aids used in this module were Powerpoint slides, write on the whiteboard, diagrams, video/animation and hand-out for reading. The aim was to underpin the concepts of numerical modelling and encouraged students with different learning styles to work independently. The lecturer used "easy to follow" structure that starts with; what is the problem, why it happened and how to solve it, using good number of examples from the real life. At the beginning of each lecture the lecturer used to remind students briefly with what they discussed the lecture before and how that is related to what will be explained this lecture keeping an eye on the learning outcomes of the module. The Powerpoint slides the lecturer used didn't include the solution of the examples the lecturer intended to solve in each lecture, instead, students had to solve these examples step-by-step with the lecturer on the whiteboard.

The lecturer tried to involve as many students as possible in solving these examples, encouraged them to participate and avoid disappointing them if the answer was wrong. Additionally, the lecturer used to leave extra examples, materials and papers for self-directed learning. Students were exposed to the theoretical and practical aspects of process modelling by the end of week four. Hence, it was the time for the invited speaker to come and explain to the students the importance of the knowledge they developed and how the numerical tools are used in industry.

Students, on a group basis, began to work on their practical project (coursework) starting from week number six. The teaching environment has been changed where the traditional class room was replaced by computer laboratory. At this stage students are required to learn how to use finite element modelling commercial simulation software. They also have to gather some information about the manufacture processes they want to model, e.g. how it works, what the relevant parameters are and how these parameters affect the process characteristics. This information is very important to accurately model the process. The learning of the selected software as well as the chosen process is triggered by enquiry. The role of the lecturer at this stage was to guide and facilitate the learning process. The lecturer explained to students that they have to work together and share responsibility for learning [4] in order to build their numerical model and get it works. Once that is done, each student within the group should use the model that was developed by his group to explore the process from different aspects. The lecturer emphasised that the aim is not to replicate previous work [15]. Instead, the developed finite element model should be used as a design tool keeping learning outcomes, by means of understanding how the process behaves and how it could be controlled, as the main outcome. The course work was assessed as following; 30% on a group presentation and 70% on final report. Student feedback was collected using Module Evaluation Questionnaire (MEQ) at two accusations, middle of the module and by the end of the module. The aim of the first questionnaire was to check if students have a clear understanding of the aims and proposed structure of the module.

3 RESULTS AND DISCUSSIONS

In general, the feedback from student was positive with an average of at least 4.0 (out of 5.0). Students had clear understanding of the aims of the module (see Figure 1a). They also digest the structure the lecturer proposed for the module, i.e. 4 weeks with different teaching aids to introduce the theoretical background and 5 weeks of EBL on a practical project (see Figure 1a).

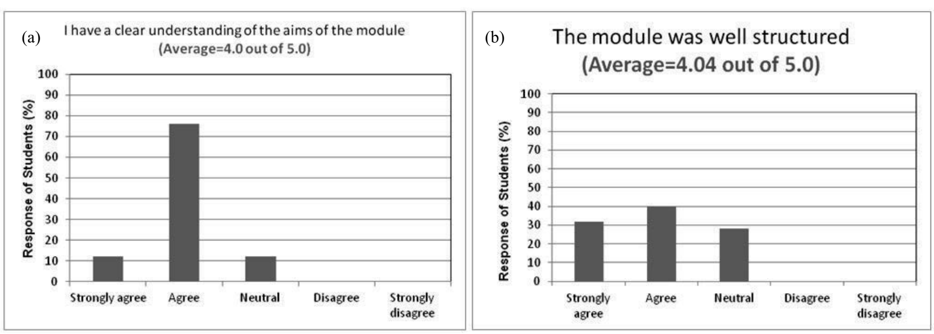

Figure 1. Student feedback on (a) the clarity of the aims of the module, (b) the structure of the module

The effect of implementing the EBL approach on student engagement can be realised from Figure 2. The feedback was positive with average of 4.0 out of 5.0. The feedback indicates that students contributed to class discussion and engaged fully with the lecturer. Additionally, students engaged with each other to complete the practical project. As a result of implementing the EBL approach, student undertook a wider independent study. Students were self-directed in learning how to do comprehensive research about the topics they selected. Additionally, they successfully modelled, simulated and understood the manufacturing processes they chose. That had a direct impact on the academic performance of students. The majority of students have performed well in the group presentation and in the final report. 20 students out of 30 have obtained marks over than 60%. The average of final marks this year was 64.9% (see Figure 3). This is relatively high average mark since the normal average mark in the School of Mechanical Engineering is between 50-60%.

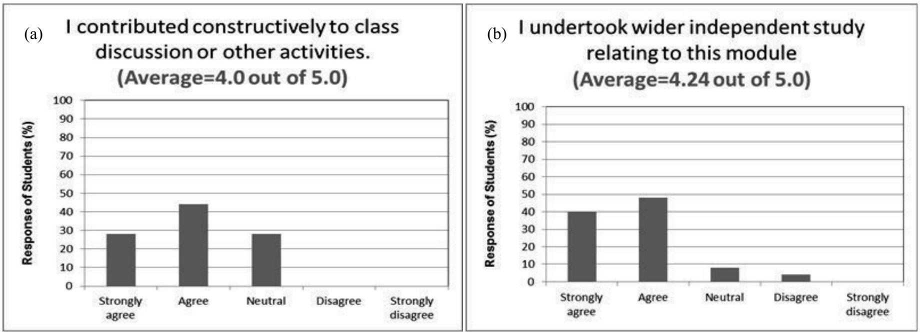

Figure 2. Student feedback on (a) the student engagement, (b) the independent study within the module

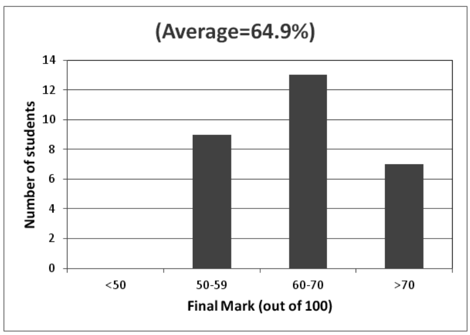

Figure 3. Student performance in terms of final mark for the academic year 2013-2014

4 CONCLUSIONS

This paper presented a study on exploring the potential of EBL in an applied engineering course. An active learning process modelling module had been achieved using EBL. This was made by replacing the classical lecturer-centred classes to EBL method. The EBL method resulted in the activation of peer-to-peer and lecturer-to-peer learning methods. The EBL technique has been used to improve the applied and personal skills in process modelling module. Despite differences in student's background, necessary practical skills were shared and EBL delivered a robust teaching tool to emerge these skills into the study program.

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PROTOTYPING PUBLIC DESIGN EXPERIMENTS AS RESEARCH — THE PROJECT OF KIC SQUARE IN SHANGHAI

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ABSTRACT
This paper looks at fostering engagement in public space by design through two aspects — optional and social activities in Shanghai KIC project. This collaborative project was developed by a team of undergraduate and graduate students supervised by researchers and teachers from interdisciplinary fields with the objective of encouraging more people to come and stay, enjoy and interact with the space. This paper describes the process and the tools used to do the public design for KIC square. Thinking about potential possibilities for a better use of the square, this project started with design for activating public space and including theories of activities as a way to test and prototype the ongoing outputs. Through the research and design process, two public design prototypes were built on the square in 2013 and both got positive data and feedbacks from the users and the managers. The result explores how design can improve the participation of users in public space.

Keywords: Public design, spatial design, square, social activity.

1 INTRODUCTION

Dubbed the Chinese version of Silicon Valley, Knowledge & Innovation Community (KIC) in Yangpu district is a multi-functional community in north-east Shanghai where people live, study, work and relax. A sunken square which is surrounded by several office buildings serves as the nerve centre of KIC, and it also faces towards the Jiangwan Stadium in the east which is a historic sports centre. Based on the connection to Wujiaochang area, the nearby commercial centre, and a cluster of universities and residences, KIC Square was built to provide a public space and supporting facilities for knowledge workers, entrepreneurs and inhabitants. However, except for specific events organized monthly, the square was not as dynamic as expected especially when compared with the huge crowds in Wujiaochang area which is only 0.66 km away (Figure 1). The absence of customer flow directly led to difficulties in the commercial operation of the square and became a challenge for attracting investment and the entering of new brands. For above reasons, the KIC Project Management Office invited a team of undergraduate and graduate design students from Tongji University to work on this project, aiming to provide possibilities for a better use of this square, to encourage engagement in different kinds of activities as well as to meet commercial needs.

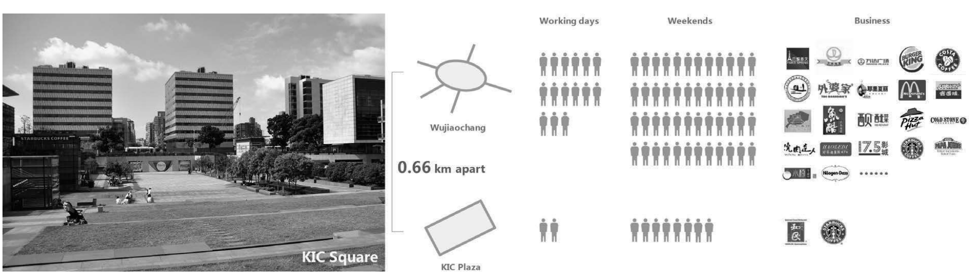

Figure 1. A comparison of the flow of people and brands between KIC Square and Wujiaochang area in 2011

2 RESEARCH AND CONSULTATIONS

The project was developed through a five-week workshop by six groups of students, and they were supervised by researchers and teachers from interdisciplinary fields. In the first week they studied the existing environment of the site and people's behaviours by on-field observation and interviews. Meanwhile they met with staffs from KIC Project Management Office to gain deeper insights. Here are some of the main problems they have found:

Landscape

- No attractive element as a landmark
- Lack of shelters & public facilities

Poor accessibility

- Entrances are not explicit and are hard to find
- The sunken shape of the square blocks the view from outside

Transportation

- Weak linkage with other landmarks nearby such as the Wujiaochang square

After taking inspiration from the context, design strategies were made to repurpose the existing public open space by adding attractive elements to promote active engagement of people from two different perspectives — optional activities and social activities.

3 THEORETICAL BACKGROUND

When talking about active public spaces people tend to first consider the relationship between the level of activities and physical elements. However, according to the research made by Zhang and Lawson [1] on common factors of good open spaces, the size and number of these spaces did not contribute to the improvement of social interactions among people. They claimed that the key to public outdoor activities would seem to be the quality of space. Thus the first step to facilitate public life in KIC Square is to find new linkages and connecting points between the users and the built environment. A lot of researches have been made to see which factors contribute to a longer stay and the promotion of physical interaction in public spaces. Whyte [2] suggests that pedestrian flow, food, sitting facilities and natural elements can attract activities in public spaces. Huang [3] argues a need for scenic space — including visual focus and plants, and activity space — including play areas and open areas. Despite all the key elements mentioned in these studies for successful outdoor spaces, they cannot work alone and must be considered comprehensively [1].

According to [4], activities in outdoor spaces can be divided into three categories: necessary activities, optional activities and social activities. Necessary activities include those that are more or less compulsory, such as everyday tasks and pastimes; Optional activities are the activities people choose to do, if time and place make it possible. For example, taking a walk to get a breath of fresh air, or standing around enjoying life; Social activities include physical contact and passive contact. Physical contact includes children at play, greetings and conversations. Passive contact includes simply seeing and hearing other people [4]. In this paper, we choose the theories of optional activities and social activities as the theoretical foundation of two paralleled prototypes. By the implementation of these prototypes we test and research on the effect and feedbacks of our design practice.

4 DESIGN PROTOTYPES

4.1 Digital trees

On the basis of a 1.5-week site analysis, the students began to develop ideas based on the public design theories which have relationship with the problems they've found. Among the problems, a lack of shelters and public facilities was considered an important issue and a starting point. Although Whyte [2] suggests that factors such as seats, trees, water and legibility of spaces encourage people to stay in public outdoor spaces, the trees planted on the KIC Square didn't work functionally as attractions and shade providers because they were too separated and were only planted close to the margins. Thus the idea of creating a multifunctional tree installation emerged. They used three design strategies: First, using several tree installations to divide the huge and empty square into smaller functional parts to a human scale. Second, each tree installation could serve as a shading shelter, a seat, a deck chair as well as a landmark which can also work at night with concentrated lightings. Meanwhile, it could also be combined with events happening on the square. Third, using abstracted and futuristic form to correspond with the context of KIC and inserting digital parts to connect online and offline services. In the next three and a half weeks, the concept was developed in detail under a periodical tutorship. Finally it turned out to be a group of installations consists of three kinds of modules. The tallest module is a tree-shaped installation with a column as the 'trunk', a screen inserted in the truck, and a piece of waved roof engraved with patterns as the 'canopy'. It was designed mainly for standing, leaning and watching. The other module is a lower 'tree' with a small platform for leaning and being used as a table to place personal belongings or laptops. The last module mimics bushes in a forest and is a repeat of the waved canopy. The form provides the function of sitting, lying, climbing and skateboarding. The patterns of all the 'tree canopies' are abstracted from the growth of tree branches with a parameterized method, and modules can be generated into all kinds of groups in a flexible way according to different needs (Figure 2). In 2013, the first implementation of digital trees was built. Although the digital part and lightings were not implemented at that time due to financial and management difficulties, it established a vision for a kind of public life we want to encourage.

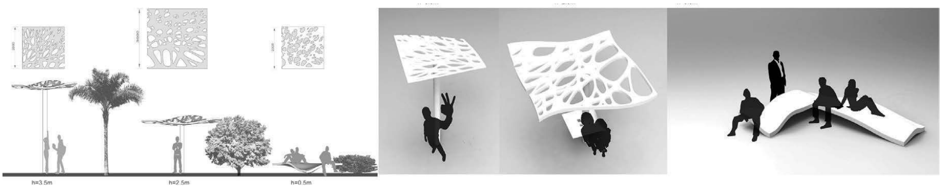

Figure 2. Three modules of the digital tree according to different functions and user behaviours

Generally, in an urban public place such as a square, the general purpose is for people to watch [4] [5]. Thus, the location of the first prototype was chosen carefully so that people can easily see what other people are doing with this installation from three directions and choose to join in. Now it is located at the east corner beside a piece of lawn with a clump of trees and is close to one of the entrances and the music fountain north-east of the square. This prototype is mainly for the research on how to promote optional activities and what influence could optional activities have on a public space (Figure 3).

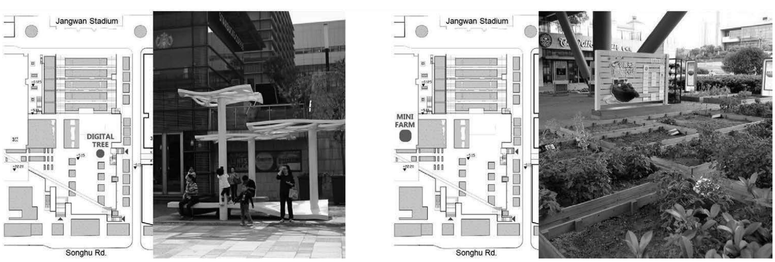

Figure 3. Location and current situation of the digital tree and the mini farm

4.2 Mini farm

The mini farm is located in the north of the square under the stretched part of building No.10. Before the launch of this project, this area was merely covered by lifeless rigid pavement. The mini farm was implemented by people from KIC who got inspiration from the design strategies of the digital trees. Because of the special location and a requirement for not blocking the view from both sides of the square, it was designed to be a combination of scenic and open play space based on Huang's theory [3]. Furthermore, they had to take into consideration people of different age and categories in KIC to attract as many people as possible, and put a little more emphasis on the office workers there. Finally they came up with the idea of building a place for urban farming so that everyone can have some engagement. It was also designed to serve as a beautiful scene which can induce people to get out of their office buildings and throw themselves into public spaces. Now this area consists of several wooden planting boxes, a shelf for potted plants and some erected boards with introductions of the plants. Meanwhile, events related to the mini farm are held such as urban farming lectures, green gifts offering, etc. All above are ways that enhance people’s experience in public spaces (Figure 4).

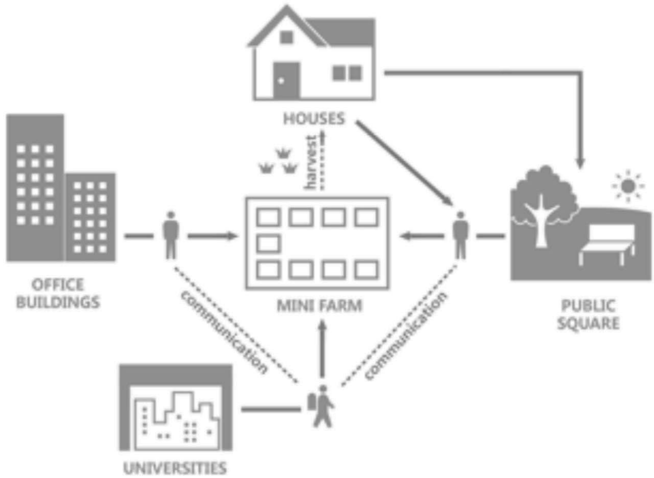

Figure 4. The system map showing how the mini farm creates interaction among different groups of people

Now the boxes are mainly distributed to companies in KIC and some organizations from the nearby universities. Residents from the surrounding community, staffs and students are all welcome. By erecting nameplates in the corner of the boxes, people can easily see which company has the best or most flourished plants. This somehow established a farming competition among the growers and urges them to spend more time taking care of their boxes.

To conclude, these two prototypes each corresponded to optional activities and social activities as entry points to design interventions. The digital tree worked as a landmark with functions such as seats, shading and play area to extend the time people spend staying on this square. The mini farm focused more on social engagement, like meeting and talking. From the point of design education, instead of simply let the students do a normal project for companies, this one was more meaningful because it demonstrated how to deal with one problem by using different strategies. It was also a rare opportunity to get their design output implemented so that by ongoing collection of data and feedbacks, they were given chances for a deeper research.

5 TESTING AND EVALUATION

This project used a combination of research tactics and design prototypes to promote public activities. The research method takes the form of observation to collect data of people's behaviours in the KIC Square. During the observation we mainly focused on people doing optional and social activities because these are the activities that can efficiently prolong the duration of people's stay in public spaces. Those who walk directly through the observed space were disregarded in the study. Meanwhile, we compared activities happening directly with or around our prototypes with activities in other parts of the square to see whether these prototypes worked in attracting people and bringing vitality.

On-field observation was conducted in the KIC Square. We classified people appearing on the square into different categories according to age and occupation. Approximate data of the amount of people and the time they spend staying on the square were collected and compared between 2011 and 2014 based on the current statistical data and research process made in 2011.

During the survey, comments on the design prototypes were collected from interviews with people in the square. Small discussions with the Project Management Office also provided additional information. The results of the survey provided an overall support for the statements in this study and further exploration.

6 DATA AND FINDINGS

Gehl [4] suggests that the more time people spend outdoors, the more frequently they meet and interact socially. Therefore we take the frequency, duration and degree of user's activities on this square into consideration as indispensable elements in the evaluation phase. Through the research, we made a record of people's activities and made a comparison of the number of people and the time they spend on the square between 2011 and 2014 (Figure 5).

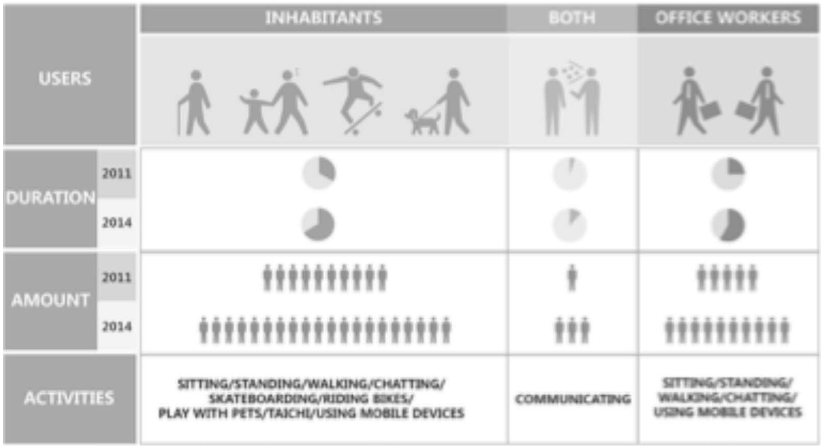

Figure 5. A comparison of the use of the KIC square between 2011 and 2014

During the observation, we found that the line between optional and social activity (especially the passive contact) is usually vague, for example, a person standing on the square could quickly engage in a conversation with other people if he wants to. So the classification made by Zhang and Lawson [1] could more accurate under such circumstance. They divides such activities into process activity, physical contact, and transitional activity. Process activity is similar to Gehl's necessary activity [4], and includes the activity between two activities when the purpose appeared clear; Physical contact occurred when more than one person had contact or interacted with another person such as talking or playing together; Transitional activity is the activity people chose without obvious purpose such as standing and sitting, but it can easily be transformed into physical contact [1]. We listed the latter two kinds of activities happening around our prototypes and other places of KIC square to see how the prototypes work. In the research, we found that the digital tree was always occupied and became a gather point of people. It mainly attracted transitional activities like sitting, standing and watching. By contrast, the mini farm had a more social function for the direct contact among people (Figure 6).

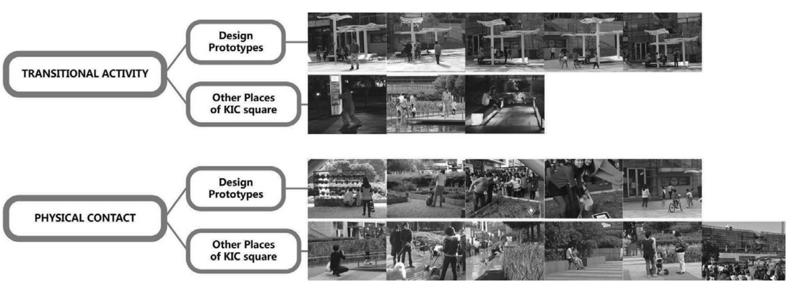

Figure 6. Observations of two kinds of activities happening on KIC square

According to observation and interviews, we've gotten many positive feedbacks. Overall, 75% of the interviewee said that these two prototypes improved their experience in the square and therefore they are willing to spend more time staying here, but some also noted that the prototypes didn't exert much effect on their activities and feelings in the square. However, the elements of the seats, shading and farming space in the design concepts were all considered valuable to the experience (Figure 7).

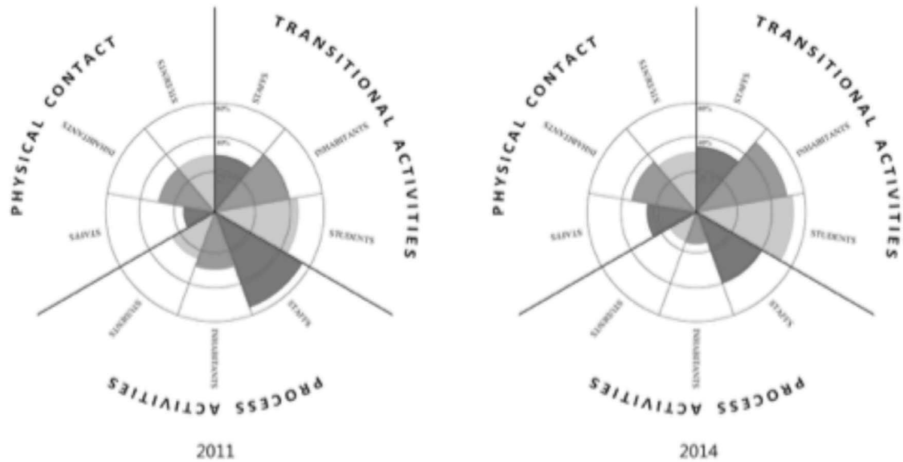

Figure 7. Comprehensive visual representation of theory and data findings

We also found that the mini farm had become a social topic of KIC and a place where staffs enjoy their spare time according to the feedback from the Project Management Office. Instead of staying inside their office buildings, now many staffs choose to spend some time watering the plants or just walking around the garden as a relaxation, especially during the noon break after they finish their lunch. Since currently the farm is run without a formal board of directors, some of them set up their own regulations of management and spend fixed time in the noon to take care of their boxes. Staffs have already harvested and brought back home some vegetables grown by themselves including carrots, eggplants and lettuce. Apart from food distribution, the mini farm played an educational role in promoting the communication between parents and children.

On the one hand we studied the effect of our prototypes on promoting activities, on the other hand, we looked for other factors that may be a contribution to the increased population of the square. We kept a record of the situation of the commercial parts in this square and found that not only the number of brands had increased, but also the brands had been taken to a relatively higher level. This is considered to be a result as well as a cause of the growing popularity (Figure 8).

Figure 8. A comparison of the brands existing in KIC square in 2011 and 2014

7 CONCLUSION AND RECOMMENDATIONS

The studies, research and considerations set out in this paper have led us to a better understanding of the factors that are conducive to promoting activities and positive interaction in public space. Despite research limitations, data and findings basically verified our expectations and assumptions of the prototypes. The digital tree mainly worked to attract optional activities and the mini farm acted upon promoting social activities. We've collected positive feedbacks from both the users and managers which shows that good design could to some extent lead to the change in people's behaviour.

Although the research of the project is still at an early stage, we will keep tracking data, and future research will concern with a comparison of effect between design and other kinds of intervention. The results of the research will be applied to continually promote the public activities in the KIC square. In the recent years a lot of problems occurred during the rapid urbanization in China and raised people's demand for a better public design. Therefore, the outcome of the research may also be applied to other public spaces which have similar problems.

ACKNOWLEDGEMENT
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ON THE APPROPRIATENESS OF APPROPRIATE JUDGEMENTS IN DESIGN EVALUATION

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ABSTRACT
This paper discusses issues related to the knowledge universities can disseminate to commercial organizations in enterprise-driven ventures. It focuses on the area of automotive design. This industry is challenged with designing small, yet desirable and beautiful vehicles. In response, we present the findings of an empirical study which aimed to evaluate if, and to what extent, previously identified automotive design principles were related to vehicle aesthetics. Automotive design experts were asked to rate a set of vehicles. Research suggests that such "appropriate judges"—as defined by shared knowledge and experience—should have a considerable degree of consensus of opinion with regards to aesthetics. However, this study demonstrated that between experts, large differences existed with regards to their aesthetic appraisal and underlying design principles. These findings are at odds with the suggestion that experts should be able to reach a high level of consensus provided the "judges" share a common education and experience in the relevant domain. This paper puts forward possible explanations for these findings: (1) a lack of agreement in terms of the meaning of commonly used descriptive terms in automotive design; (2) existing descriptive principles may not fully account for differences in appreciation of automotive aesthetics; (3) philosophical issues related to 'essentialising' terminology which characterizes human experience. We conclude by suggesting that through conducting design research, academics may be able to challenge preconceived notions in design. This ability may in turn fuel design innovation and thus may be very valuable in enterprise ventures between universities and commercial organizations.

Keywords: Aesthetics, automotive design, expertise, enterprise-driven research, user experience.

1 INTRODUCTION

In the current climate, universities are increasingly expected to engage with commercial organizations in enterprise-driven ventures. This paper focuses on how design research may inform the automotive design industry with regards notions of perceived beauty. It is argued that trends in automotive technology will see vehicles becoming smaller and lighter making them more conducive to electric drive [1]. Predicated on the assumption that, over time, electric vehicles will be similar in terms of their technical attributes, quality and price, customer enthusiasm and uptake will to a large extent be determined by their visual appearance [2] [3]. This poses an interesting challenge in that larger vehicles are seen as being more desirable and beautiful [4]. In other words, how do we design small, yet desirable and beautiful vehicles? Clough [4] examined our understanding of automotive beauty using a range of methods including surveys, interviews with experts, and visual analyses. From this, Clough [4] created a design framework which included 8 key aesthetic design principles regarded to be of importance in the design of beautiful small cars. According to this framework, the design—with regard to exterior styling—should be *simple*, *elegant*, *well-proportioned*, *flowing*, *sculptural*, *minimalistic*, *fluid*, and *understated* [4].

This paper reflects on the findings of an empirical study. The aim of this study was twofold. First, it set out to empirically evaluate if, and to what extent, the above automotive design principles were related to vehicle aesthetics. In order to conduct this evaluation automotive design experts were asked to rate images of small urban vehicles in terms of their aesthetics as well as the extent to which they had incorporated each of the design principles. Secondly, the level of agreement between experts was investigated with respect to the judgment of aesthetics and the proposed design principles. In the field of art, findings of large inter-subject variability in judgments of aesthetics have given rise to the relativistic idea that there are no universal standards [5]. However, it has also been suggested that considerably higher levels of agreement can be reached provided observers share common characteristics [6]. According to Amabile [7] “appropriate judges” (i.e. those familiar with the domain in which the product was created) are able to make objective evaluations. Given their shared characteristics, we expected to observe high levels of agreement not only with respect to the evaluation of vehicle aesthetics, but also with regards Clough’s [4] design principles. The design principles were expected to lead to high levels of agreement among this group of experts based on the fact that the principles emerged from interviews and surveys with car design experts, arguably reflecting a common design language and understanding of automotive beauty. In reflecting on these results, this paper discusses the value of academic research in challenging the universality of design principles. This in turn may provide an opportunity for academics to engage in enterprise-driven collaboration with automotive design professionals in order to aid them reflect on the design process and notions of aesthetics in design.

2 METHOD

2.1 Participants

In this study we exploited the availability of an extremely homogenous group of experts with respect to art-and design-related education and experience. These factors have been shown to be strongly related to aesthetic preferences [6]. A total of eight experts participated in this study. All participants were male with a mean (SD) age of 46 (7.7) years. The “appropriate judges” in this study consisted of UK based educators in automotive design, all of whom previously worked as professional car designers for a minimum of 3 years.

2.2 Stimuli

The stimulus set consisted of 14 compact urban vehicles (see table 1). Compact urban vehicles were chosen to control, at least to some extent, for difference in vehicle type and size and focus on the aesthetic differences within this specific category. Within this vehicle class, a wide selection of typical and novel designs was included. For each vehicle design a three-quarter perspective was shown in greyscale to control for any possible colour effects on aesthetic appreciation.

2.3 Procedure

Each vehicle was presented to participants on a 23 inch monitor for 10 seconds. Following the presentation of each vehicle, participants were asked to rate to what extend they agreed with the statement that “visually, this is a beautiful object” on a Likert scale ranging from 1 (fully disagree) to 7 (fully agree). Participants were then asked to evaluate and rate each of the 12 vehicle designs according to the aforementioned 8 design principles identified to be of particular relevance in the context of automotive aesthetics [4]. Using a 7-point Likert scale (1 = fully disagree; 7 = fully agree), participants were asked to indicate to what extent each vehicle design incorporated these principles.

2.4 Statistical Analysis

The level of agreement was operationalised as the Intraclass Correlation Coefficient (ICC) which is a statistical measure of the consistency with which different “judges” (i.e. design experts) rate a given trait (i.e. aesthetics, simplicity, etc.). The ICC takes on a value between 0 and 1 where the former indicates the absence of any consistency, and a value of one perfect agreement. Returning to 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 [6]. Given the homogeneity of the expert group in this study, as well as the use of everyday objects (i.e. cars) which show only limited artistic variation when compared to artworks, we hypothesised high levels of agreement within our expert group.

3 RESULTS

3.1 Aesthetic rating

Table 1 shows the minimum, maximum, mean, and Standard Deviation (SD) of the aesthetic ratings for each of the 14 vehicle designs. The designs are presented in order of preference with the most preferred design (Mazda Kiyora) in the top left, the least preferred design (MIT Citycab) in the bottom right. The results show large variations in aesthetic ratings amongst the experts. As judged by the size of the standard deviation, the Lotus City car (SD=1.9), Tata Pixel (SD=1.8), and Mitsubishi MIEV (SD=1.8), showed the lowest level of agreement regarding its aesthetics. The highest level of agreement was observed for the Smart (SD=0.6), and MIT City cab (SD=0.9).

Table 1. Minimum, maximum, mean, and standard deviation (SD) of aesthetic rating for each design from most (top left) to least aesthetically pleasing (bottom right)

Design	Min	Max	Mean	SD	Design	Min	Max	Mean	SD
1. Mazda Kiyora	4	7	5.4	1.1	8. MIEV	1	6	3.5	1.8
2. Tata Pixel	2	7	4.5	1.8	9. Kia Pop	2	6	3.5	1.3
3. Lotus Citycar	2	7	4.4	1.9	10. Citroen Crab	2	6	3.4	1.2
4. Organic	2	6	3.9	1.5	11. Smart	2	4	3.1	0.6
5. Nissan Leaf	1	5	3.6	1.3	12. Suzuki Q	1	5	2.6	1.2
6. Honda commuter	2	5	3.6	1.1	13. iMove	1	4	2.6	1.2
7. Toyota IQ	2	5	3.6	1.1	14. MIT Citycab	1	4	2.0	0.9

3.2 Correlations

Table 2 displays the correlations between all ratings assessed in this study. All 8 design principles showed significant and positive relationships with aesthetics. The highest correlations were observed for “well-proportioned” (.57), “elegant” (.55), and “flowing” (.45). “simple” (.20) and “understated” (.24) showed the lowest correlations with aesthetics. Table 2 further shows that several of the principles showed significant positive correlations with each other suggestive of overlap between the different principles. To further investigate the relationship between the principles, a factor analysis with varimax rotation was performed. The analysis revealed two factors with eigenvalues larger than 1. The factor loadings of the different design principles are shown in table 3.

Table 2. Correlations between mean ratings on scales for experts

	Aesth	Simple	Elegant	Prop	Flow	Sculpt	Minimal	Fluid	Under
Aesthetics	1.00	.20*	.55**	.57**	.45**	.33**	.31**	.31**	.24*
Simple		1.00	.54**	.37**	0.19	0.16	.66**	0.19	.59**
Elegant			1.00	.76**	.56**	.57**	.54**	.54**	.42**
Well-proportioned				1.00	.44**	.45**	.38**	.34**	.34**
Flowing					1.00	.65**	.30**	.88**	.27**
Sculptural						1.00	.37**	.69**	.26*
Minimalist							1.00	.27**	.70**
Fluid								1.00	.27**
Understated									1.00

* p<.05. ** p<.01

3.3 Reliability – Intraclass correlation coefficients

The reliability of judges’ ratings was assessed by calculating intraclass correlation coefficients (Ri) for each scale. The intraclass correlation is not the correlation between a predictor variable and the dependent variable but it reflects the extent to which members of the same group tend to act alike. It is the proportion of the total variability in the measured factor that is due to the variability between individuals. Since all observers independently judged the same set of designs, Ri (ICC (3,1) – also known as ICC (CONSISTENCY) – was considered most appropriate [13]. For each of the ratings, the intraclass correlations are presented in Figure 1.

Table 2. Factor loadings of the 8 design principles

	Component	
Design principle	1	2
Simple	.060	**.864**
Elegant	**.633**	**.583**
Well-proportioned	**.529**	.476
Flowing	**.908**	.112
Sculptural	**.831**	.166
Minimalist	.200	**.855**
Fluid	**.908**	.082
Understated	.138	**.817**

Factor loadings greater than .50 are printed in bold

The intraclass correlations showed that the interrater reliability for aesthetics was low indicating little agreement amongst the experts. Regarding the 8 design principles, the least agreement was observed for the principles “understated”, “sculptural”, and “minimalistic”. In contrast, “fluid”, “flowing”, and “simple”, showed the highest level of agreement among the experts.

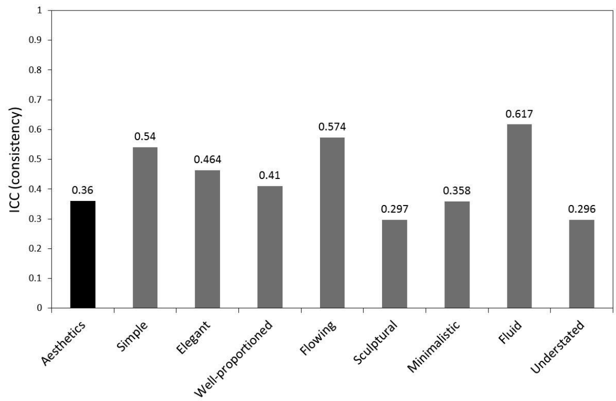

Figure 1. Intraclass Correlation Coefficients (ICC) for aesthetic ratings and the 8 design principles

4 DISCUSSION

The aim of this study was twofold: the empirical validation of (1) the role of several automotive design principles in the perception of aesthetics, and (2) investigation into the level of agreement between experts with respect to the judgment of aesthetics and proposed design principles. The results of the correlational analysis showed that the design principles identified by Clough [4] were significantly related to aesthetics and indicate that automotive beauty is indeed associated with these principles. “well-proportioned”, “elegant”, and “flowing” were shown to be particularly strongly associated with an individual’s perception of automotive aesthetics. However, the results also demonstrated that between experts, large differences existed with regards to both their appraisal of the vehicles’ aesthetic and the extent to which the designs incorporated each of the different principles. These findings appear to be at odds with Amabile’s [7] aforementioned suggestion that experts should be able to reach a high level of consensus provided such “judges” share a common education and experience in the relevant domain. Unlike aesthetic qualities, design principles are less ambiguous and idiosyncratic due to their close association with physical object characteristics. Therefore, it is perhaps even more difficult to understand the lack of agreement with reference to the design principles. In this context, it is also important to realise that the principles were derived from a large body of domain knowledge existing of published automotive literature, surveys, focus groups and interviews involving automotive design experts. As such, the principles at first instance appear to have high face validity. Phrases such as “rolling sculpture” [8], “Fluid rooflines” [9], and “Perfectly Proportioned” [10] also allude to the relevance and ubiquity of these terms in automotive design. Thus, despite the ubiquity of these automotive design terms, there appears to exist little agreement as to what these terms mean. This surprising notion may provide an opportunity for academics to engage in enterprise-driven collaboration with automotive design professionals in order to aid them reflect on the design process and ideas of aesthetics in design.

The study showed that many of the principles are highly correlated with each other (see table 2) suggesting that the principles may be tapping into the same underlying construct. This was confirmed by the factor analysis indicating the existence of two components or underlying constructs. The first component included “elegant”, “well-proportioned”, “flowing”, “sculptural”, and “fluid”, whereas the second component consisted of “simple”, “elegant”, “minimalist”, and “understated”. Subsequently, we hypothesise that the second component may reflect the more fundamental principle of “unity in variety”. According to this principle, humans prefer objects that have as much complexity or variety as possible with a maximum of unity or order [5]. Similarly, the first component appears to be related to the Gestalt principle of “good continuation” which states that the aesthetic experience of objects is improved by arranging its elements along common lines. Future research is required to explore these underlying constructs further in the context of automotive design but the results would suggest that the list of principles identified by [4] may be too limited to account for the appreciation of automotive aesthetics. This provides a further opportunity for academics to engage in enterprise-driven collaboration with automotive designers.

This paper has discussed whether we can identify design principles underlying automotive aesthetics. In utilising language to describe design principles, one assumes that language is capable of describing certain *essentials* of product form. For Huetwell [11], the notion of essentialism necessitates that the existence of "underlying reality or true nature […] that gives an object its identity". Consequently, ""categories (such as 'boy', 'girl,' […]) are real, in several senses: they are discovered (rather than invented), they are natural (rather than artificial), they predict other properties…" [11].

With the above in mind, it can be argued that Clough's [4] research assumes that Huetwell's [11] examples of 'boy' and 'girl' may be replaced with terms such as 'simplicity' or 'elegance'. Through conducting statistical analysis, this paper has argued that Clough's [4] 8 essential terms can be further reduced (essentialised) to 2 terms, namely 'good continuation' and 'unity in variety'. Through discussing how humans may experience design, it is possible to critique this process of essentialism. Olivier and Wallace [12] argue that reducing individuals' experiences of design to a set of immutable data can diminish the value of human heterogeneity. Being edicts, design principles are a form of 'immutable data' for they attempt to describe—in the words of Huetwell [11] —"an underlying reality or true nature […] that gives an object its identity". Following Olivier and Wallace's [12] argument, we suggest that design principles insufficiently describe the study participants' experiences of the designs presented to them in the primary research. Philosophical debate regarding the nature of human experience may provide a further opportunity for academics to engage in enterprise-driven collaboration with automotive design professionals in order to aid them reflect on important drivers which influence the sales of vehicles. Research on the nature of experience is particularly important to the automotive industry because of the notion manufacturers must adhere to the tenets of the 'experience economy' [14] to increase profit margins.

5 CONCLUSION

Research suggests that "appropriate judges", as defined by shared knowledge and experience, should have a considerable degree of consensus of opinion with regards to aesthetics in art and design. This paper has reflected on the results of a primary study in which expert judges in the field of automotive design exhibit great disagreement with regards to not only aesthetics but also design principles associated with aesthetic design. This paper has highlighted three issues which may have contributed to these findings. Firstly, we suggested a lack of agreement in terms of the meaning of commonly used descriptive terms in automotive design. Secondly, we argued that existing descriptive principles may not fully account for differences in appreciation of automotive aesthetics. Finally, we referred to philosophical issues related to 'essentialising' terminology which characterizes human experience. We suggest that these three issues provide avenues for academics to engage in enterprise-driven engagement with the automotive design industry. Such engagement benefits industry and creates revenue. It also serves as a valuable method to contribute to knowledge in the peer-reviewed academic world through methods of dissemination in conferences and journals. The academic rigor of such avenues help to maintain the intellectual integrity of university-industry enterprise-based endeavours.

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Chapter 15

Problem Based Learning

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
3 & 4 SEPTEMBER 2015, UNIVERSITY OF LOUGHBOROUGH, UK

IMPROVING SKILLS IN PRODUCT DESIGN: EXPLORING SOLUTION SPACE AND THE IMPACT OF APPLIED MENTAL SCALING

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ABSTRACT
This paper explores how mental scaling may constitute a creative tool in product design education, in order to improve design solutions through different methodological approaches. The increasing expectations from industry on optimization within product design are clearly evidenced today. These demands are often defined by specific user groups or corporate product managers, putting a pressure on designer's propositions. How can we as educators prepare our students for these requirements? In a real-life product design project, the creativity potential is reflected through a requirement specification framing a certain solution space which the design has to comply with. In academia, our challenge is to encourage our students to question the rigidity and limitations given by this requirement specification and its inherent solution space. Experience gained from practicing design methods enable design students into building sufficient courage and self-awareness in order to challenge this creativity potential. Our experience from teaching design methods indicates that practicing mental scaling - or mental elasticity - enables the students to do so. When applied to a design project, the ability to mentally fluctuate between abstraction and concretization builds a thematic divergence which generates an open and sensitive mind-set. This mind-set enables the student to utilize this creativity potential through individual procedural diversity. These abilities have been observed and assessed through practical assessments. The thematic divergence in these practical exercises has produced a valuable body of experience, which contributes to articulate a firmer understanding of the effect of these methodological approaches.

Keywords: Product design, design methodology, solution space, mental scaling, procedural diversity.

1 INTRODUCTION

In order to provide stimulus for creativity, one has to understand how stimulus affects student behavior. Challenges adapted to students' current development level is an important condition for students' intellectual growth [1], and we acknowledge that both creativity and performance are key abilities in commercial design practice today. Due to the fact that demands from users and industry are putting increasing pressure on designers, there is need for building experience from practical assignments that simulate the challenges design students later on will meet in realistic situations. In the design field the ability to contribute with relevant competence in cross-disciplinary cooperation between different actors seems to be important part of design practice. In this framework, it is vital for teachers in academia to understanding how design students are enabled - through relevant theory and teaching - to respond to the demands given by industry, and to build experience through practical assignments. In this view we acknowledge that emphasis on research on relevant design methods is required, and this paper aims at building knowledge around how different methodological approaches may influence the outcome of creative exploration. In particular, our focus in this study is the students' mind-set, which determines how an idea generation process develops and responds to a given design task.

1.1 The scope and design case

The scope for this study is a design case where a group of 26 industrial design students on foundation level were supposed to develop three sets of cutlery: an everyday cutlery, a "fine" cutlery and a disposable cutlery, during a period of seven weeks. One important aim was to encourage the students to investigate aesthetical expressions through exploration of individual materials, during individual design processes where they freely could choose the succession of activities as well as their own methods and tools. Introductory lectures were given in order to enable the students to build awareness around cutlery as cultural phenomenon. Through careful form-studies the students were asked to make physical mock-ups, and to describe how each element of the cutlery relates to each other.

1.2 Research methodology

Three different research tools were used in this study; observations of the tutoring sessions in the workshop and in the studio, photo documentation from the workshops and studio exhibition, and finally a written questionnaire. Our research question was: In what way does the act of mental scaling influence the solution space and potential produced during the idea generation phase of the assignment? Our hypothesis was that individual, procedural freedom could encourage students into individual mental navigation which would produce distinct and diverse design qualities possible to identify and to describe as result of diverse mental journeys.

2 DEFINITIONS

In order to understand how the terms solution space and mental scaling relate to each other, there is a need to define their meaning as well as to describe their impact on a typical idea-generation process.

2.1 Solution space

The term solution space [4] represents a total body of creative potential, framed by the design brief for the required design solution and the actual time limitation for the task, figure 1. In addition, solution space is framed by mental scaling between an abstraction level and a concretization level. The solution space constitutes an imaginary space where the total collection of idea resources may be generated and mapped before a final solution is selected through a convergent process instructed by the design brief.

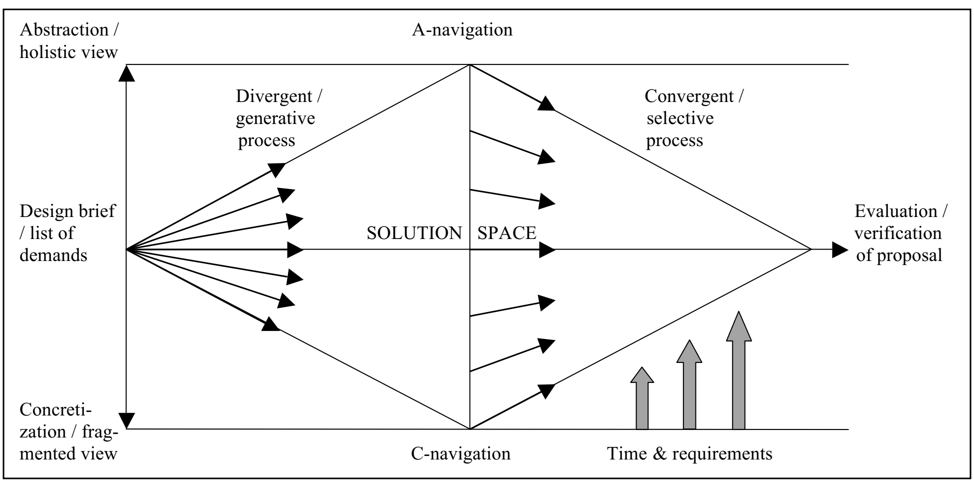


Figure 1. Solution space

2.2 Metal scaling

In order to understand the reason for decisions made by each individual student, there is a need for mapping personal characteristics - or procedural capabilities - that each student holds. Student capability parameters describe the ability to navigate on the mental navigation scale [2]. Mental navigation characteristics [3] describe the mind-set or personal attitude a student holds in order to perform through process. This attitude is described in two characteristics, A-navigator, and C-navigator. On a mental scale spanning between abstraction and concretization, the A-navigator tends to navigate within the abstract sphere, typically triggered by holistic, abstract thinking, strong in the idea mapping stage, but often lacking the required attention to final details. The C-navigator on the other hand tends to navigate within the concrete sphere of the mental scale, typically triggered by concrete, fragmented thinking, often having limited ability to discuss overall, conceptual, strategic, ethical or philosophical issues, often weak on idea mapping, but with strong attention to details in final design. By referring to the Markus / Maver map of the design process, Lawson [5] suggests that a separate internal loop of analysis, synthesis, approval and decision should be integrated into each step of the general process from initial proposals to detail design. In many ways, this model matches our philosophy for our design case. De Bonos [6] theory discusses the power of lateral thinking in developing new ideas. By following this line of thinking, mental scaling - or mental elasticity - describes the ability to consciously navigate between divergent and convergent thinking, enabling mental iterations during a design process. This ability to fluctuate between abstraction through a holistic view and concretization through a fragmented view while exploring potential solutions during the solution search process seems to be an essential capability for designers in order to attack a given problem from different angles in order to explore and produce optimal solutions to a defined problem.

3 THE STUDY

In order to establish an overview of the diversity of the physical models being made during the assignment, each artefact has been classified by using a graphic display. Through individual evaluation, the models have been mapped and positioned in a matrix map - figure 2 - spanning between traditional and conceptual qualities on an aesthetical scale, and between abstract and detailed level on a mental scale framing the span between A-navigation and C-navigation.

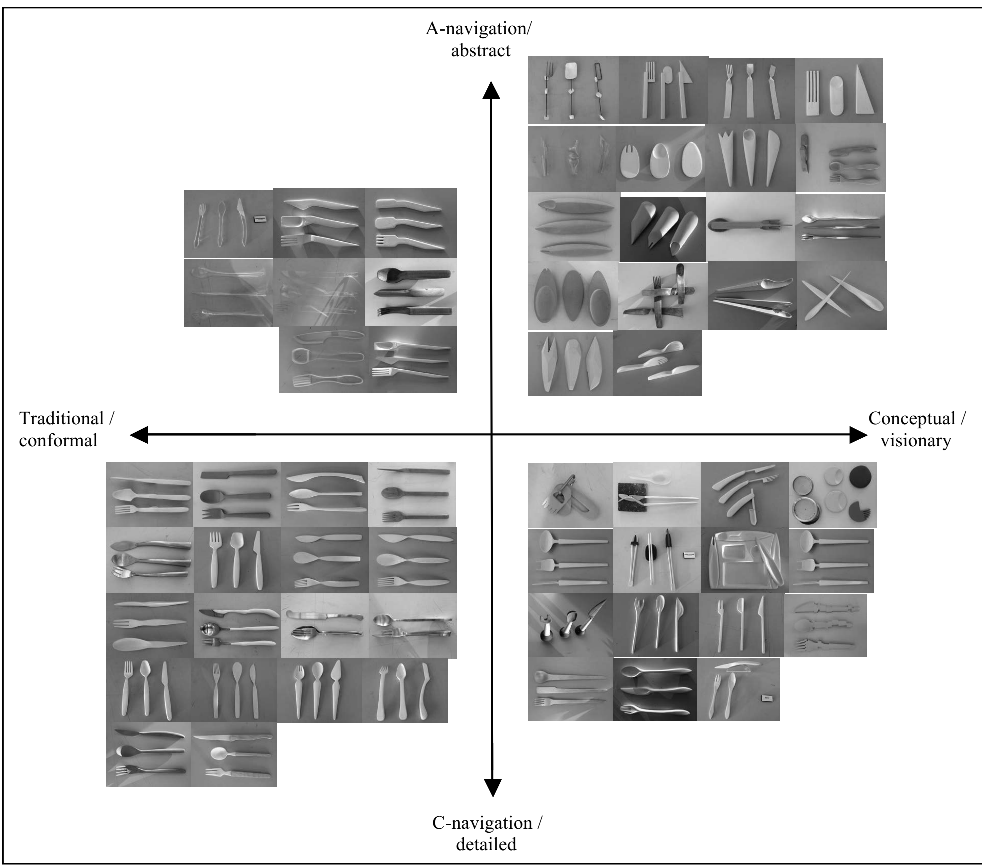


Figure 2. Qualitative matrix – A-navigation vs. C-navigation combined with personal preferences

3.1 Typological classification - examples based on qualitative matrix

In order to get an overview of the diversity of the physical artefacts being made, a typological matrix may support the understanding of reasons for implementing aesthetical qualities into each cutlery.

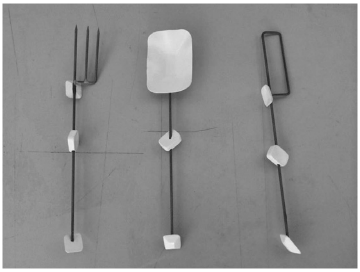


Figure 3. Result from A-navigation and Conceptual / visionary mind-set

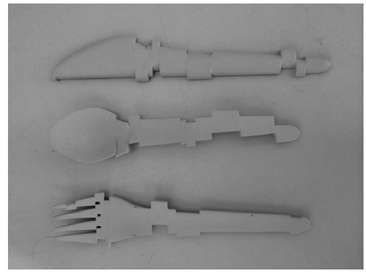


Figure 4. Result from C-navigation and conceptual / visionary mind-set

Figure 3 describes a set of cutlery with a high level of A-navigation together with a highly conceptual or visionary mind-set, where many of the formal typological form characteristics [7] well known from cutlery have been removed, and a set of new initial shapes have been introduced. Only the strictly necessary functional areas between skin and artefact have been kept. This model typically displays rough surfaces almost on mock-up level, which also explains how this student has had a strong conceptual mind-set while forming these objects, while spending limited attention to detail.

Figure 4 describes a set of cutlery with a high level of C-navigation together with a highly conceptual or visionary mind-set, where a formal origin has been dissolved and reduced into a pixel-image which only just holds a minimal resemblance of a knife, spoon and fork. The student aimed at keeping the aesthetical qualities within a digital-like framework introducing 2D graphical effects into a 3D shape, giving this cutlery a low functional preference when it comes to practical use.

Figure 5. Result from C-navigation and Traditional / conformal mind-set

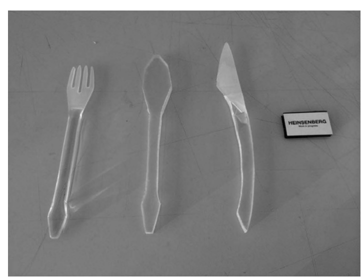


Figure 6. Result from A-navigation and Traditional / conformal mind-set

Figure 5 describes a set of cutlery with a high level of C-navigation together with a highly traditional mind-set holding conformal preferences, where many of the typological form characteristics well known from traditional cutlery have been preserved. This set is carefully produced in steel, and a set of new shapes have been carefully integrated into the models with the ambition to continue aesthetical traditions found in Scandinavian cutlery. This set holds a high attention to detail, and this submission explains how this student had a strong traditional mind-set while forming these artefacts.

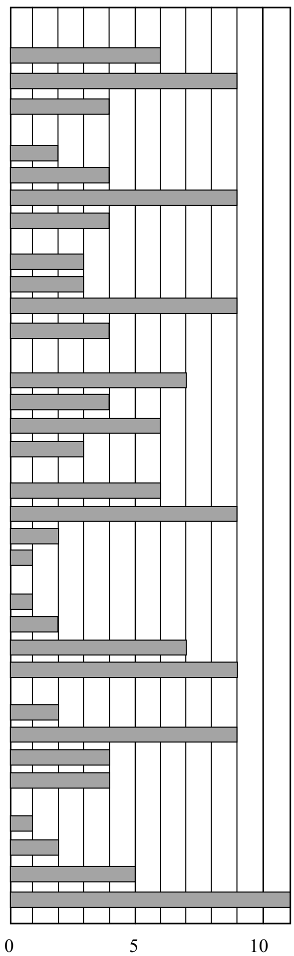
Figure 6 describes a set of cutlery with a high level of A-navigation together with a highly traditional mind-set with holding conformal preferences, where some typological form characteristics well known from cutlery have been preserved. The introduction of transparent plastic material into traditional cutlery forms creates a new way of looking at cutlery. However, these artefacts display rough geometries almost on mock-up level. This student has had a traditional mind-set while forming these objects, and while spending limited attention to detail, this student decided not to challenge the formal aspects of traditional cutlery.

4 RESULTS

In order to qualitatively evaluate the feedback from students in a post-perspective view, the following questionnaire was distributed to the students, and their answers are presented in this table:

Table 1. The questionnaire

	Statement	Answer	Count
1.	*"I like best to work conceptually and visionary with overarching thoughts and problems, not details"*	Do not agree	0
		Partly agree	6
		Quit agree	9
		Totally agree	4
2.	*"I like best to work concretely with the small details in drawings and physical models"*	Do not agree	2
		Partly agree	4
		Quit agree	9
		Totally agree	4
3.	*"In the cutlery project I first sketched many solutions and then selected one that I developed further"*	Do not agree	3
		Partly agree	3
		Quit agree	9
		Totally agree	4
4.	*"In the cutlery project I started with one suggestion, which I adapted and developed to a final solution"*	Do not agree	7
		Partly agree	4
		Quit agree	6
		Totally agree	3
5.	*"In my design work, I answer only within task text frames, I do not like to take unnecessary risks"*	Do not agree	6
		Partly agree	9
		Quit agree	2
		Totally agree	1
6.	*"I like to challenge myself and to stretch myself beyond my own borders in my design tasks"*	Do not agree	1
		Partly agree	2
		Quit agree	7
		Totally agree	9
7.	*"I prefer to work alone since then I am able to concentrate best"*	Do not agree	2
		Partly agree	9
		Quit agree	4
		Totally agree	4
8.	*"Having freedom to experiment freely in the design tasks has been good".*	Do not agree	1
		Partly agree	2
		Quit agree	5
		Totally agree	11



4.1 Focus areas and findings

To get an overview of the student capability parameters, table 1 is divided into different focus areas. The questionnaire constitutes three main focus areas:

- Q1+2: The distribution between A-navigation vs. C-navigation attitudes
- Q3+4: Generative / procedural path through project
- Q5+6: Risk and personal challenge
- Q7+8: Attitude towards process

When evaluating the distribution of answers from the respondents, a lot of interesting answers emerge. The answers from Q1 and Q2 do not constitute a clear indication towards either A- or C-navigation, but indicates a quit even distribution between these two characteristics. This indicates that a majority of the students either have a mixed influence from both A- and C-navigational capabilities, or that the distribution between pure A-navigators and pure C-navigators could be even. This relation is reflected in figure 2, where a quit even distribution of qualitative positions are found both on upper section as well as on the lower section of the mental scale spanning from A-navigation to C-navigation.

The answers given from Q3 and Q4 somehow contradicts with each other, because they indicate that a majority of the students went through both a divergent idea-generating process while in the same time going through a convergent selection process ending with one solution for final refinement. This might indicate that the students had problem with understanding what the question actually asked for, or had a reduced recognition of their own process in a post-perspective view. It seems that the questions should be re-formulated. Q5 and Q6 indicates a strong willingness to take risk, and to challenge own borders. This could also indicate a willingness to challenge both design brief and list of demands for the solution, as well as the expected solution space. Q7 indicate a preference towards working alone, since concentration then is often obtained and appreciated. Q8 indicate a strong appreciation of procedural freedom, as this has contributed positively to the process.

5 CONCLUSION AND REFLECTIONS

By encouraging the students into exploring different procedural approaches and to different approaches in their design processes, a wide diversity of processes and final results have been evidenced. Our hypothesis of identifying and describing design qualities as result of diverse mental journeys is to some extent verified by our study. It seems that procedural freedom to individually explore design processes encourages students into individual mental navigation, constituting catalyst for creativity. Given this particular scope, the study indicates that the freedom to go through mental fluctuation between abstraction through a divergent view and concretization through a convergent view may contribute towards a rich design process. It seems that the stimulation of an active switching between holistic and fragmented view trigger the students' explorative minds, being dependent of a necessary amount of courage to explore and to challenge conformity. Procedural freedom has been appreciated, and this stimulation seems crucial in order to accomplish a steep learning curve during formal teaching in this case study. However, to plan and manage formal teaching while encouraging students into free, explorative and experimental design approaches has been challenging. It would be fruitful to study a larger number of design assignments in order to produce a more solid body of evidence and documentation, 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. By its total body of information, this study has produced new and valuable insights on the utilization of relevant design tools, and how design methodology can contribute as a creative asset during the learning journey.

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THE PROBLEM REVISITED: TEACHING THE PBL APPROACH TO DESIGN STUDENTS

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ABSTRACT
Problem-based learning (PBL) is becoming increasingly popular in design educations, but how is it taught and practiced? This paper presents a case study of a three-day workshop that has the purpose of introducing PBL to design students. A theoretical background on PBL and problems in design is established and is backing up the case study. The study shows that design engineering and architectural students without experience in PBL in general finds the approach to be beneficial when working on a design challenge in a student team.

Keywords: PBL, problem statement, case study, foreign students.

1 INTRODUCTION

Design is taught in a wide span of educational environments across the world, and the pedagogical setting in which it is taught most probably differs just as much. At [university X], the problem-based learning approach [1] is a deeply rooted part of the educational tradition and it is, hence this, implemented across all educational departments, including all design-oriented department at the university.

Throughout the bachelor level at the university's design educations, students slowly gain confidence in handling design challenges in this problem-based and project-organised setting in teams of 4 to 6 students. However, at the Masters level at [X university], a high number of foreign students each year come to study without prior knowledge or experience with the problem-based learning used in this specific educational environment. As the various study activities are also most often carried out in groups with fellow students, it is important that these new students from abroad quickly learn and experience the problem-based approach. Therefore, a three-day workshop is held each year as part of their introduction to the specific study form of project-organised PBL.

The PBL-workshop takes the students through an intensive concept development process. In this process, the focus is on working in teams on a predefined design challenge and on explicating the continuous evolution of the problem, they try to solve.

This paper presents the structure of the workshop, which is build around framing and reframing problems that the students try to solve in relation to a given theme. During the workshop a series of pin-up sessions are conducted, and at each session, the student groups present their progress and revised versions of the questions they are trying to answer with their design proposals. The series of questions that a single group develop by iterating on the design task throughout the workshop shows how the focus converges from being broad and often unclear to being narrow and specific. The aim of this explicit workshop rhythm and setup is to show each student that working with a design challenge can often be seen as an on-going dialogue between problem and solution where both parts are continuously visited and revisited [2].

Besides from the workshop setup, the paper also presents an evaluation of the format from the involved students. The evaluation is primarily based on written student reports, and the result from the evaluation is furthermore discussed and analysed in relation to existing theory on design thinking and problem-based learning. The driving question of the paper is: *How is PBL effectively taught to students on master level in the field of design?*

The rest of the paper is composed as follows: Section 2 presents a theoretical background on PBL, problems and solutions in design and certain perspectives on contrasting process management models. Section 3 describes the case included in this research and the related data. The results are found in the fourth section of the paper, and finally, the paper is concluded with a fifth section that discusses the results with certain perspectives on further research.

2 THEORETICAL BACKGROUND

In many ways the fundamental concepts and structures of problem-based learning resemble the ideas of several well-known planning- and design process-models. In this section some of the pertinent concepts and models are presented and related to each other.

2.1 Problem-based Learning in General Education

Problem-based learning is a relatively new pedagogical approach that started to gain footing in the 1960's and 70's. Barrows and Tamblyn published their research on the reasoning abilities of medical students after experimenting with new learning styles. From the traditional approach, where students answer questions from information supplied by a lecturer, the problem-based approach propose problem scenarios that encourage the students to engage themselves in the learning process by independently realising what knowledge they need to acquire in order to understand and solve the problem [3][4].

The following list in Savin-Baden and Major [4] sums up the classic understanding of problem-based learning based on the findings of Barrows and Tamblyn [3]:

- Complex, real world situations that have no one 'right' answer are the organizing focus for learning.
- Students work in teams to confront the problem, to identity learning gaps, and to develop viable solutions.
- Students gain new information through self-directed learning.
- Staff act as facilitators.
- Problems lead to the development of clinical problem-solving capabilities

The list of PBL characteristics includes self-directed learning, meaning that the students themselves define the problem in focus and the knowledge gabs they need to overcome. The problem formulation – despite its volatile nature – then drives the learning activities towards a further elaboration of the problem and its possible solutions. Typically, students work together in small teams, and together they establish their strategy on how to gain the needed knowledge in order to move forward on problem they set out with. Lecturers and teachers act as supervisors to the student teams. Not by dictating certain literature or investigations, but instead by gently pushing the teams in the right direction.

Problem-based learning has a resemblance to experiential learning and the work of Dewey [5]. According to Dewey, education is a process of continuous reconstruction and growth of experience. To sum up, the problem-based learning process is a process that takes its departure in a given – and often ill-defined – problem. The student team then searches for knowledge and insights that can help the team cast new light on the problem and create a basis for a further elaboration of the problem and possible solutions. As Dewey suggest, this process is a continuous process of learning and gaining new experiences.

2.2 Problems and Solutions in Design

From the PBL definition by Savin-Baden and Major, we have learned that real world situations have no one right answer, and according to Rittel [6] and Buchanan [2] similar conditions exists in regard to design problems. Rittel defines design problems (and planning problems in general) as *wicked problems*, which are characterised by being:

- Difficult to define
- Perceived differently from person to person
- Without a clear set of criteria for whether a solution is right or wrong
- Symptoms of other problems

From this we may derive that problem-based learning activities carried out in design educations revolves around problems with these characteristics, and also that these problems to a large extent fit well with PBL as defined by Savin-Baden and Major [4]. But how do design students tackle the ambiguity of the wicked problems that they are exposed to? An answer to this question is suggested by Lawson [7] in his classic study of two groups of students: final year students of architecture and postgraduate science students. In this study, Lawson experiences a difference in solution strategies:

"… they learn about the nature of the problem largely as a result of trying our solutions, whereas the scientists set out specifically to study the problem." [8]
What Lawson suggests is that experienced architectural students are not only analyzing the problem at hand, but also synthesizing solutions in order to achieve a better understanding of the problem. This oscillating movement between analysis and synthesis is depicted in several design process models. Two models are shown in figure 1 below.

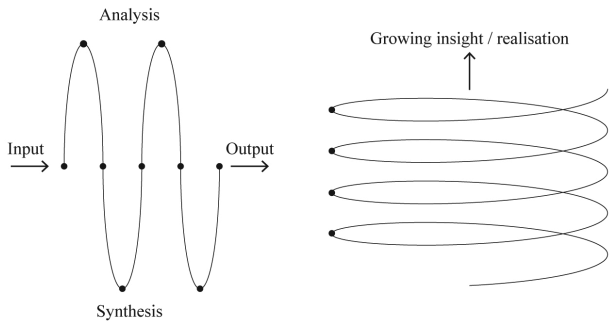

Figure 1. The two models present the design process in each their way. The model to the left shows the oscillation between synthesis and analysis, whereas the right model depicts the realisation process as a hermeneutic circle with growing insight in a cyclic process.

From the two models in figure 1, it looks like the design process could be never-ending, but according to Cross [9], the overall process must converge:

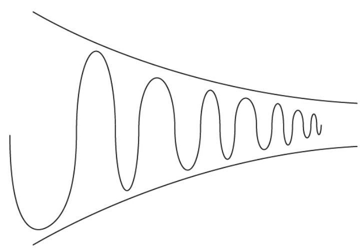

Figure 2. According to Cross [8] the oscillating process between synthesis and analysis – or as some denotes it: the process of divergence and convergence – must converge in the long run.

As it will be shown in a later section of the paper, the workshop carried out with foreign students was based on this same assumption of an overall converging problem statement.

2.3 The Strength of PBL in Design Education

Returning to the problem-based learning approach, one could ask what value PBL adds to design education when the fundamental process of design already holds similar ingredients, such as an ill-defined problem as starting point and continuous iteration between problem and solution? At University X, emphasis is on methodological solidity and clear rationales in the design engineering process. This is achieved through PBL elements such as a clear problem statement to bounce up against; and PBL thereby offers student teams an important explicitness and transparency in the design process. Stolterman [10] distinguish between to fundamental approaches to design education: the guideline approach and the aesthetic approach. Whereas both approaches are recognised as important qualities in design at University X, PBL helps to facilitate a learning approach closest to the engineering-like guideline approach.

2.4 Suitable Process Management Models for PBL in Design Education

As the models and definitions shown earlier suggest, the fundamental principles of problem-based learning in a design context, must be an empirical approach. Simply put, an assumption of students or teams knowing how to solve a given design task and with a steady hand prepare a perfect project plan at day one, would be false. Instead, student teams typically navigate into unknown terrain (the ill-defined problem) with no clear picture of what resources or insights are needed in the beginning of a design project. The choice of process management tools should reflect this ambiguity and openness in the design project.

In the case to be presented in the next section, time boxing and early feedback loops has been used as tools for managing and guiding the process. In contrast to practical tools such as Gantt charts [11] that have the purpose of planning far ahead and create an overview in given project, time boxing [12] solely offers a steady tact and frequent inspection and revision of the project's current state. Depending on the extent of the project, a time box can last from as little as a few hours to a couple of weeks. At the end of each time box, the project status is reviewed and discussed, and eventually an updated problem statement is formulated. The concept of time boxing derives from Agile Development [13] in the domain of software development and is perhaps best known as Sprints from the process management framework called Scrum [14]. The "fail early, succeed sooner" mentality of frequent project reviews fits well with the problem-based learning format as it promotes an active discussion and revision of the current-state problem formulation.

3 CASE DESCRIPTION

The case presented in this paper is a specific PBL workshop that serves as an introduction to the educational environment at University X. The workshop is placed in the beginning of the first master semester and is aimed at the foreign architectural and industrial design master students that come to study at the university without prior experience with the PBL. The workshop runs over three intensive days with several time boxes and project review sessions. All groups were asked to develop a new concept for a specific square in the city, leaving the decision to the group about what problems related to the square to work on. The overall structure of the workshop is shown in figure 3 below.

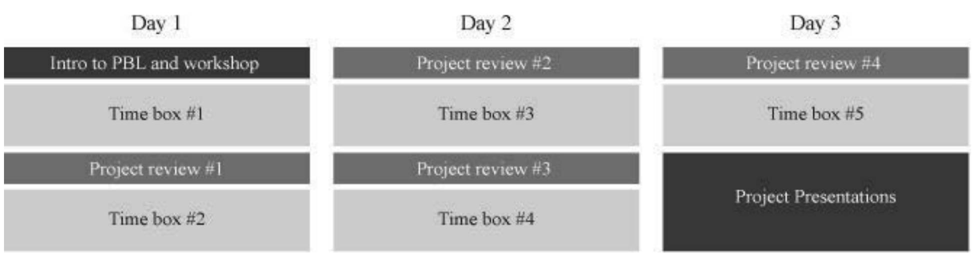

Figure 3. The workshop is structured as short time boxes approximately three hours each. In-between the time boxes, the projects are collectively discussed through rather fast-paced project previews.

The workshop was conducted with groups of four or five students, and at each project review, the groups were asked to present a revised version of their problem formulation. An example of the continuous elaboration of the problem formulation from one group is shown in the list below: How can two different characters coexist?

1. How can pedestrians and cars coexist on the square?
2. How can we design the public square according to flows?
3. How can we maintain the flows of cars and pedestrians on and around the public square while improving the experience of people temporarily staying on the square?

The list above shows an increasing level of detail in the different versions of the formulated problem. The group from this example started out with a rather vague problem formulation, but during workshop time boxes, the students immersed into the problem by researching the location, observing traffic flows, interviewing users, looking into legislation and city regulations while also proposing sketchy and conceptual ideas for possible solutions. At the project reviews, the group presented their progress and deeper understanding of the problem through a revised problem formulation. Step by step

they thereby achieved an increasingly articulated idea of what basic problem they really needed to solve.
Similar examples exist from the other six groups in the workshop. In general, the lists of problem formulations from the seven groups show a pattern of increasing detail and awareness of the problem in focus. Most of them converge from being rather broadly defined to becoming increasingly narrower and goal oriented. However, the problem formulations also shows a couple of instances of totally reframing the question in the problem formulation and leaping backwards in order to pursue a completely other direction in the project.

4 RESULTS

This section is based primarily on the students' reflections about the course of the workshop and their personal learning outcome, but also on the teachers' experiences of the workshop.
From a teachers' point of view, it seems clear that students without prior knowledge or experience in working this actively with the formulation and re-formulation of a driving question initially have a certain difficulty in actively using the problem formulation as a primary driver of the project. However, during the workshop it was also observed that students were starting to use the current state problem formulations as a basis for an ongoing discussion about the course of their projects. One student elaborate on the strength of the problem-focused approach to working on design projects in groups:
"The [PBL] model was successful during the problem orientation stage; the opportunity to be able to bounce ideas between group members was highly effective as individual members were able to provide different perceptions of the site. As such we had a richer selection of potential problems, which would later formulate the basis for our design."
As it is indicated in the quote above, the problem formulation assists the students in explicating their respective understandings of the project outset. However, several students found the collaborative project proposal activities in the groups difficult, as they were not used to work on design tasks collectively as a team, but only as individuals. Despite this, most students found the method fruitful and emphasised the benefits and precision of using the problem formulation as driver in the projects. Another student's reflects upon this:
Asking a question is for me a totally new technique to start a project and it may lead to a completely different result but it is probably also more precise. By asking a question you have to get the deeper sense of the project. You become more are aware of what, why and how you are creating a piece of architecture.
The latter quote indicates that the PBL approach raises the students' level of awareness towards why and what they are doing. This is very much in line with the general aim of PBL and the thoughts of Dewey about experiential learning: Learning activities should build on the previous experiences of the students and direct them to new experiences that further their growth [4].

5 DISCUSSION AND FURTHER PERSPECTIVES

This paper presents a case study of a three-day workshop on PBL within the domain of design education. In order to back up the case, a brief theoretical background that relates PBL and design problems to each other has been presented.
From the case it has been investigated how the PBL approach is implemented as an introductory workshop for new students at the master level of the design education at University X. It shows that the foreign students – despite their cultural differences and educational backgrounds – found that the PBL approach was a practical and efficient tool in strengthening the awareness of what activities the student groups were carrying out and needed to carry out in order to progress. From the lists of problem statements developed throughout the workshop, it was seen that the student groups increasingly narrowed down the project focus in each new version of the problem statements. However, it also showed some cases of students that had to return to their starting point and pursue a new direction of the project. The task of explicating the problem formulation continuously in a workshop format this intensive had not been done before, and the study showed that its transparency helped the students as well as the teachers in aligning the project and the supervision.
It is clear that a short and intensive workshop with the purpose of introducing a new learning approach also has some shortcomings. The limited time and the fact that the students did not know each other occupied a large part of the metal resources on the student level, and given another setup, these

resources could have been allocated to learning and understanding the PBL approach. The case presented in this paper is also an example on how strict time boxing can be carried out in a rather fast pace and support faster project review loops. On the fourth industrial design bachelor semester at University X, students work in a similar way, but in slower pace. This allows for the pursuit of another depth in the project and for the students to work in practice with synthesising new solutions for the design problems.

From the experiences with the case in this paper, it is clear that several directions for further research could be followed. The case represents a face-paced time boxing tact that directs the learning activities in a certain way. It may be fruitful to pursue a more flexible combination of various-length time boxes that adapts to the specific project activity. A deeper look into the framing and reframing of the problem formulations could also prove interesting. Hopefully the case presented in this paper will initiate a discussion about how PBL is taught and could be taught in general design educations.

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PROJECT TIME BOXING AND MILESTONES AS DRIVERS FOR OPEN DESIGN PROJECTS

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ABSTRACT
The Curriculums and programs in Problem Based Learning (PBL) utilizes the project-format in a team based setting for rehearsing the competencies of applying the design-oriented skills and knowledge learned in courses and workshops. If the project period is self-organised, there is a tendency to start out with low speed and push the workload forward because the deadline is far out in the future. When approaching deadline the workload intensity increase creating an asymmetric effort over the project period (9-11 weeks).
So how can we create a sense of urgency in longer project periods, not just workshop format, that would help a team of design students to engage and drive the project from the start to achieve more and get further in developing their projects? - Without interfering with the content and development of the project it self, but helping the team to move forward and become focused in their project development. This paper discusses the effect from students participating in a time-boxed project module with five milestones for 2nd.MSc semester in an Industrial Design Engineering program. The semester evaluation, the process reports and supervisor perspective is very positive and that the structure, strict enforcement and rolling project management responsibility in a group work setting really helps them drive the project forward with high motivation. The main challenge lies in the balance between loading the teams with too many challenges and just providing them with enough structure to create the sense of urgency that fuels motivation and sparks ideas.

Keywords: Milestones, time boxing, sense of urgency, open projects.

1 INTRODUCTION

Design processes can be difficult to navigate and manage due to their complexity [1], unpredictability and open ends [2] If the design engineering problem is more open, the ill-defined nature of the wicked problem [3] will also add the difficulty of planning activities and creating the drive and sense of direction needed, especially in the early phases of innovation and product development – as engineers sometimes refer to as fuzzy front end [3].
In an educational setting where many of the prerequisites, expectations and conditions from the real world are suspended, it can be very hard for a group of students to push hard and work dedicated from the very beginning of the project period. There can be a tendency to push the workload forward because there ‘is plenty of time’ and they may not have developed and scoped the project yet, creating a fuzzy perception of what they are doing. This general phenomenon of postponing the work of a study until deadline is closing in is called procrastination [4] and is not exclusive to group based project work at universities. But open theme projects where students have to frame and define their project on their own and the fuzziness in beginning of the design and development process contributes to the lack of factors pushing the group.
Brainstorming and ideation sessions in a workshop setting use the mechanisms of time boxing to create a sense of urgency that may spark creativity and speed up the process ([5]. The time framing adds pressure in the sense that the participants must perform at this instant. At the same time the limited time allows for participants to just let go and focus on the task at hand, because of the facilitated format where ‘disturbances’ are eliminated. If successful the state of creative flow is achieved [6].
But in longer projects (10-20 weeks) the workshop format is not sufficient to support the development process. So when graduate design engineering students are to learn and demonstrate how navigate and manage their own projects, how can we support their process without taking control of their projects?

In the Industrial Design Engineering curriculum of a Problem Based Learning (PBL) University the 2nd.MSc. project period has been redesigned after a curriculum revision in 2012 and has served as basis for testing new large-scale time boxing with six milestones in a 10-11 week project period (15 ECTS). At this stage in the Master program part of the learning objectives is that the students demonstrates the ability to plan, execute and reflect on the design process with a very high degree of interdependence, including researching, scoping and defining their own project focus and content within very broad theme.
At the same time the project period is relatively short, the project topic and approach is open and complex with a need for rapid development, test and decision and evaluation in a high pace if an acceptable result is to bee achieved.
This paper outlines the project management tools, process, intermediate deadlines and explicit expectations that have been implemented in order to achieve the needed propulsion and drive in the project groups from the beginning of the project period and maintain the sense of urgency throughout the project period.

2 METHODS

The project period is broken down into six phases that follow a prediction of the expected process, following the key learning objectives for the project module. The students need to demonstrate the navigate and execute a rapid design and development process where they elicit and identify user needs and transform these into a market description, from which potential key stakeholders can be identified and a design brief created. A concept for a coherent solution is developed, and key aspects are developed further in details including manufacturing, construction and production aspects, always with a clear link to the essential insight into the user needs.
The forecast is contradictory to the unpredictable nature of an open-ended process with multiple iteration, thus it only serves as a guideline, not a strict and fixed format. The content of a Milestone that describes the expected outcome and current state of the knowledge build in the project at the current stage. The project is pitched and presented at the end of each phase.

2.1 Milestone structure

The Milestones (see Table 1) are not meant as fixed goals and the only scope the project group should work on in the phase. There are a couple of important additions; firstly the project groups are encouraged to work ahead, or at least take future Milestone content into consideration for the current phase. Secondly project groups are encouraged to start the ideation from the beginning of the project period to avoid an exclusively analytical approach, but maintaining the abductive reasoning characteristic for Design Thinking [7].
That means that the project group can be working in parallel with content designated for several Milestones during a phase, which also naturally occur at any iteration that involves content from previous phases.
The time allocated for the six Milestones phases are not the same. In first three Milestones are only one week each with the intention to both set a fast pace from the beginning and the fact that a five days work period is easier to overview and break down than two-three weeks. It also provides a faster framing and scoping of the project since the first three Milestones are closely related to the contextual setting and objectives for the project. To some extent the idea of having deliverables in sprints from SCRUM [6] and focus on task break down is transferred to the larger project scale with the Milestone content and presentation as the deliverable.

2.2 Presentations

Each Milestone ends with a presentation session where all groups present their project status. This is not new in it self within the Industrial Design Engineering curriculum, where midterm status seminars have been implemented from the beginning in 1997 when the program began.
In an attempt to increase the pressure, and thus sense of urgency, several new initiatives are implemented. Firstly, the responsibility of the presentation is rotates in the group, so only one person gives the presentation for each Milestone. Secondly senior students, guest professors, alumni, etc. are invited to the sessions to give feedback. Having new people in the audience each time means that the group cannot rely on the audience to ‘know’ their project in advance, thus the presentation much be accumulative and represent the project at the given stage.

Students are asked to divide their presentation time into two separate sections. They are given three to five minutes for a pitch, with the focus on 'selling' the idea and convincing the audience that their project is relevant, interesting and worthwhile pursuing.

Table 1. Overview of Milestones

Milestone	Content	Time available
One	***Client & Need*** Identification of user-organization or representative (the Client) and description thereof. Identification, description and verification of needs (think observations, interview, research-data, etc.)	One week
Two	***Market and Business Concept*** Business plan to broaden from specific need to general market need (this includes development budget and target prices). Market description (size, type, segmentation, etc.) Sales and marketing strategy – light reflections on where and how to sell and market the to-be-proposed product/service.	One week
Three	***Organisation and Design Brief*** Proposed solution for network and /or organization of the solution (actor-network and for services also service map or offering map – see Servicedesigntools.org for inspiration) Design Brief as basis for product/service design concept phase. Must include target production cost/unit.	One week
Four	***Product/Service concept*** Overall concept description/visualization Highlighted features, functions, aspects that meet the needs and demands from design brief. Main challenges in production and manufacturing (product parts) and main challenges in implementation (service part).	Two weeks
Five	***Details*** Detailed exemplary dives into several aspects such as (choice depending on solution, and should be argued): construction, production, technology (template for this may be used), assembly, form, operations (e.g. buttons/dials), use of product, etc. Key chosen aspects should be supported by exemplary calculations, experiments/models and analysis of these.	Two weeks
Six	***Handing in reports*** Clear summarized description of proposed solution linking exemplary dives goes into the Product Report and the highlighted process description with main investigation, development and reflections goes into the Process Report	One to one and half weeks

The underlying principle being that there is no point in having great ideas if you cannot convince other people (potential investors, stakeholder or your manager) that it is interesting and worth pursuing.
The second section of the presentation is a project status, where the focus shifts to process, methods, current challenges and future actions. The underlying principle being that the project group needs feedback and advice on their approach to the project.

3 ANALYSIS

Looking at the level of procrastination it is experienced as significantly less than previous semester projects, but a direct comparison is difficult to make, since the project theme and approach vary. But there are three different sources of data to allow for some comparison to the experienced difference when comparing this five tight defined Milestone & Pitch structure with a 'normal' two to three status seminar structure used on other semesters in the Program. First interviewing the Supervisors, second source is the official Semester evaluation and third source is the reflection chapters in the Process reports by the Project groups.

3.1 Supervisors experience: faster framing and longer in the process

Since 2012 a total of four supervisors has been involved in executing the project module, with one supervisor acting as co-supervisor for all groups. This supervisor is also involved in numerous other programs and can therefore compare this project module to other modules also operating with Milestones-like seminars. In a direct comparison to a project module in an Entrepreneurial Engineering Masters program with only three and more loosely defined Milestones he describes the difference in the following way.
One of the main differences is the strict enforcement of the tight schedule with high pace and high expectations. This effect is evident in the precision of their description of their project during the Milestone presentations and the work they do from the beginning of the project. They simply get further in the development process. (Rephrasing of Poul Kyvsgaards statement during Milestone at Entrepreneurial Engineering, December 2014).
As another supervisor points out the short deadlines between the first three Milestones forces a faster framing of the project, including the opportunity to reframe. (Louise Møller, February 2015).
So seen from supervisors' point of view the Milestone and time-boxing is forcing a faster framing of the project and allows for the group to get further in the development process compared to previous projects.

3.2 Students direct evaluation: pace & challenge

The student steering committee and the main coordinator do an official semester evaluation after each semester. This includes evaluation of course modules, physical setup and the project module. Looking at the comments regarding the project module in 2012, 2013 and 2014 provide a relatively coherent feedback from the students on the structure of the Milestone as a mean to improve the pace in the design process.

- *"Milestone, important exercise. Good with many Milestones" (2012)*
- *"The push which the supervisors have given have really had a great impact on the process" (2013)*
- *"Length of the milestones have worked great" (2013)*
- *"A very good structure - A nice change and challenge - Good with the milestones, pushing you forward", "It has been stressful, but it was nice to challenged." (2014)*
- *"The project period has been really exciting and the milestone structure has been super motivating"(2014)*

In these evaluations the main feedback themes are on the structure and pace provided by the Milestone structure and content and the challenge of the Pitch presentations done by the Project manager.

3.3 Process reports demonstrate better process understanding and management

During the three seasons several projects have been forced to make significant changes or complete new problem statements (Problem Based Learning context) during the projects. Most of them have done so within the first two Milestones (representing two weeks), when the presentations at the Milestones did not convince the audience of the relevance of the need or the approach to solving it. An example of this is the Aphear project from 2013 [8], where the group started out with the scope of addressing the need for consuming less water. After the second Milestone where the group was not able to frame the need in a relevant setting where they could engage the problem from a design angle they completely changed the project in phase 3 and achieved a very fast turnaround catching up with the other teams at Milestone three (see Figure 1). This was partly due to the group already knowing the approach from the previous two weeks, but also because they were already working at a high pace, not postponing the workload.

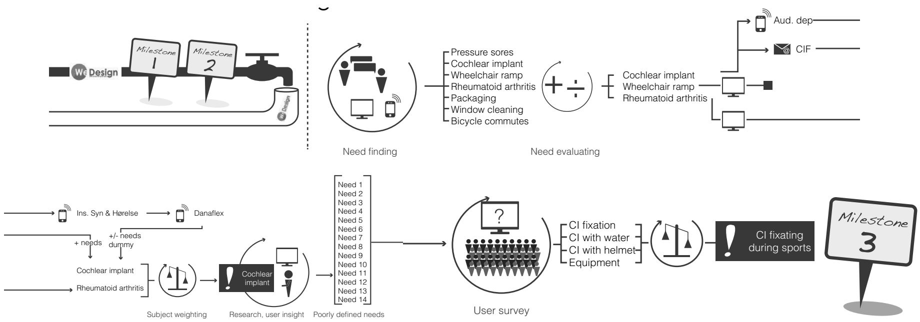

Figure 1. Process illustration from Aphear project Milestone one to three

In another project the group describes the experience of the Milestone structure and the relation to the fuzziness in this way:

"As the project started out with a bracelet monitor and ended with an alarm system, the group has gone through a lot of different features and functions to either aid the design, product or the business model [….] Amongst the group it has become clearer to spot when the process is slowing down and the passion for the project is dissolving and how to steer clear of these situations.

It has also been useful to complete the assignment of project managers as well as being responsible of presenting the project each milestone. This has returned both practice in presentation skills as well as confidence and a higher level of ownership and insights in the project and solutions" (Group Five, 2014)

It also indicates that they have gained a greater understanding and awareness of maintain pace and energy in the project. Furthermore the rotating role of presenting at the Milestone seminars also seems to have increased their individual sense of ownership.

However not all groups have taken ownership of the content needed to be filled into the Milestone structure as Group Two states in their process report in 2014 [9]:

"They have functioned as a good guideline, but as a planning tool, they have not functioned optimally during this project."

Thus indicating that the structure might set a stage and an incentive for pushing forward in the project, but it does not provide enough in terms of planning.

"The intention of integrating SCRUM might have worked better if the project manager (scrum master) had not been exchanged every milestones, due to their individual way of managing the project. It requires a lot of resources to integrate a new method into the project work and as the project came closer to the end, the method was pushed aside." [10]

This indicates that the rolling role of project manager and presenter at the Milestone, not only allows the individual members to increase ownership, but it also creates variance and unevenness in the way the project is managed.

4 DISCUSSION

Even with an almost entirely positive feedback from supervisors and students, there are some interesting parameters to continue experimenting with and some key unresolved issues. First of all there is the balance between pushing and pulling the students forward to avoid procrastination, one aspect of this is the balance between control over the project and supporting the group, another is the balance between encouragement and high standards that challenges students performance level.

The balance between controlling the design process on behalf of the groups (pull) and supporting them through structure, frames and intermediate deliverables must be related to the learning objectives for the project module (push). The students at 2nd M.Sc level must be able to navigate a design process by choosing the appropriate methods and procedures and reflecting on their outcome and relevance to the problem. This is means that the specific approach and choice of methods, decision and evaluation on project content and direction is the group responsibility with the presentations for new audiences at the Milestone seminars provides the group with a possibility to make a reality check on their own assumptions without supervisors' interference. So far the project module has been executed with a very clear distinction regarding the responsibility and ownership of the project content and specific approach being the group's responsibility. This mainly pull approach with supervisors exercising a 'hands-off- principle will not change due to the learning objectives.

The other aspect of balancing encouragement with high explicit expectation to performance on both process management, presentations and pitch and developing new innovative solutions with a sound business perspective. This balance is more fluent and more difficult to manage explicitly and there is a risk of creating too much tension between the current state of students' capability and expectation of future state. So far this gap has not been too big as the evaluation and feedback shows. As an example of the gap is the case of only single group member at each Milestone is giving the presentation provokes a lot of anxiety, but as feedback and reflections in the reports shows the experience both instills confidence and allows all group members to take ownership of the project. The encouragement is provided in the form of supervision that focuses on supporting the student to make decisions, but not specifying which decisions to make.

5 CONCLUSION

Setting Milestones in a project is not new in it self, but a combination of a rigor strict enforcement, rolling project management with one person in charge (in a group work environment) and face pace with short time between content driven Milestones and including an accumulative Pitch session provides an effect on the projects and their management.

Supervisors see the effect on the faster framing of project and thus the possibility to develop the proposals further into detail having more time allocated for this part. The students acknowledge that they are challenged individually as project managers to define tasks, methods and procedures that will allow them to achieve the goals for next Milestone, but it enhances their design project management skills and reflection level.

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LEARNING-BY-WATCHING AS CONCEPT AND AS A REASON TO CHOOSE PROFESSIONAL HIGHER DESIGN EDUCATION

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ABSTRACT
This paper discusses the concept of learning-by-watching, defined as learning through visual observation and critically connected to Dewey's concept of learning-by-doing. It then presents and discusses learning-by-watching as a reason for choosing professional higher design education based on a questionnaire given to novice university students in their first year at three different Norwegian institutions of design education. The research concludes that watching family and professional designers seems important, but none of the students mention observing design teachers at previous schools as a reason for their choice to pursue professional higher design education. This finding could indicate that design teachers in Norway continue to follow the Forming doctrine, where showing students how to design was nearly forbidden.

Keywords: Learning-by-watching, learning-by-doing, John Dewey, professional higher design education.

1 INTRODUCTION

What is *learning-by-watching* and how important is it in choosing a professional higher design education? In order to answer this question, the empirical material for this investigation is based on a questionnaire given to first-year students from three design education programmes at the university level in Norway.

I connect the concept of *learning-by-watching* [1] to John Dewey's *learning-by-doing* and critically discuss his concept based on his own writings and on the aforementioned survey. The concept that I have developed, *learning-by-watching* [1], is a new term related to an old phenomenon, which runs parallel to Wenger and Lave's [2] *communities of practice*: 'Although the term may be new, the experience is not' [3:7]. My intention is not to deny the importance of doing; rather, it is to extend the meaning of learning-by-doing [4] to include learning-by-watching. The first portion of this paper focuses on defining learning-by-watching through the framework of learning-by-doing.

2 LEARNING-BY-WATCHING WITHIN LEARNING-BY-DOING

2.1 Learning-by-doing

Because learning-by-doing is connected to John Dewey, it is important to discuss aspects of Dewey's theories relevant to my current theme, *learning-by-watching*. Dewey was a pioneer and leader in the radical progressive education movement in the United States at the turn of the twentieth century, together with his colleague and friend George Herbert Mead [5]. Some ascribe the origin of the phrase 'learning-by-doing' to J. A. McLellan's 1889 volume, *Applied Psychology,* which used the following motto: 'Learn to Do by Knowing and to Know by Doing' [4]. Later, Dewey criticized parts of the radical education movement for its narrow understanding of learning-by-doing. He felt that the movement reduced it to activity, making it synonymous with experience.

Dewey inspired and influenced the writing of McLellan in *Applied Psychology*. Dewey was not a co-author, although his name appeared alongside McLellan's in an American edition published sometime after 1892 [6]. According to the title page of the current edition of the book, McLellan was the director of normal schools in Ontario, Canada [4]. For years, this book was unavailable in libraries worldwide, so I suspect that many authors actually never read the original source of the learning-by-doing concept. McLellan mentions ‘learn to do by knowing and to know by doing’ several times in the book. First, he mentions the phrase when discussing what he calls the ‘…fundamental in *every stage of mental growth*…’ [4:44, author’s emphasis]; this phrase refers to educational principles in primary, secondary and higher education. The first stage he states, is *Mechanical*. The second is *Repetition of the principle of the mechanical stage* [4:45, author’s emphasis]. He continues on the same page:

> There is one dictum of modern pedagogy which, *under proper limitations*, finds its application here: *Learn to do by doing*. This principle is by no means co-extensive with the whole of education, and is in fact much abused by some educational ‘reformers,’ but it is the basis of all early training. Reading can be learned only by reading; spelling only by spelling; writing only by writing; the fundamental operations of number only by performing them, and so on. The teacher must aim, therefore, at thoroughness and continuity of repetition, and while having constantly in view the *dawning intelligence* of the child, must avoid *undue* reliance upon the *rationale* of the subject-matter, and undue appeal to a reason as yet undeveloped [4:45, author’s emphasis].

Already in this first introduction to the learning-by-doing concept, it seems that McLellan, inspired by Dewey, criticizes parts of the radical education movement for its narrow understanding of learning-by-doing, reducing it to activity. Further, under point 4, *Learn to Do by Knowing,* he writes, ‘It appears, then, that the maxim, “learn to do by doing” is, after all, but the complement of a wider and profounder principle *learn to do by knowing’*. [4:47, author’s emphasis]. Under the subtitle, *Training of Impulses. 1. The development of the intellect,* McLellan again mentions, ‘The child cannot *do* until he *knows*’ [4:129, author’s emphasis]. Then, under point *3*, *Knowing and Doing must, therefore, be trained by the same process, and correlatively to each other,* he makes the following statement:

> We are now able to state the psychological principle which reconciles the two precepts already given (pp. 45 and 46), ‘Learn to do by doing’ and ‘Learn to do by knowing.’ The principles when rightly interpreted include rather than exclude each other. Unless we *do,* we cannot *understand the ideas involved in action,* much less act. And unless we *know*, we cannot *understand the ideas involved in action*, much less act. And unless we *know*, we cannot act in a significant way, in a way which is really expressive of ideas [4:130, author’s emphasis].

Finally, under the subtitle *Criticism of Maxims. 3. Learn to Do by Doing*, McLellan continues with this statement:

> The principle becomes false when it loses sight of the ideal factor, the element of knowledge required for doing; and when it implies that the doing should be merely habitual or mechanical. It, therefore, requires a supplement: *Learn to do by knowing*. We might combine the maxims, and say: *Learn to know by doing, and to do by knowing* [4:182, author’s emphasis].

Here, McLellan actually explains the motto for the book, which is seen as the origin of the learning-by-doing concept. In the book’s preface, McLellan mentions Dewey’s influence on his writings, saying that ‘the general mode of treatment in the part on mental science is that of Professor Dewey, whose work on Psychology has been so well received by students of philosophy’ [4:vi].

2.2 Dewey’s critique of the interpretation of the learning-by-doing concept

Later, Dewey in his book, *Schools of Tomorrow,* stresses that ‘learning by doing does not, of course, mean the substitution of manual occupations or handwork for text-book studying’ [7:255]. Thus, learning-by-doing seems to be a synonym for experience, and he stresses, ‘the hands, the eyes, the ears, in fact the whole body, become sources of information…’ [7:255]. Dewey includes reading in doing, and he also mentions *watching* processes and products as part of the learning-by-doing concept [4]: ‘the little children go into the shops as helpers and *watchers*, much as they go into the science laboratories, and they pick up almost as much theory and understanding of processes as the older children possess’ [7:255, my emphasis]. Further, on the same page, he writes, ‘Since sixth grade children are old enough and strong enough to begin doing the actual work of repairing and maintaining the building, in this grade they cease to be *watchers* and helpers and become workers’ [7:255, my emphasis].

2.3 Learning-by-watching

I developed the concept of learning-by-watching through my doctoral work about how Inuits or Eskimos learned to design and make vernacular contemporary clothing in North Alaska. Throughout childhood, the Inuit children learned just by watching the women designing and making numerous garments at home. They never tried to make anything by themselves during childhood, and there was no active teaching. Nonetheless, when they tried for the first time as grown-ups, they managed to design and make the entire garment on their own, including a special kind of advanced trimming, the *qupak*. I do not believe that the ability to make Inuit clothing was an intrinsic skill among the Inuit. There must have been a learning process for gaining design mastery and for gaining competence in the making of these garments, yet this learning did not occur in schools or courses but within the homes of the Inuit. To a large extent, designing and making Iñupiaq clothing was tacit knowledge expressed through practice rather than through words, particularly according to visual matters of the design, whose considerations are different from technical matters. When learning happened non-verbally, particularly through learning-by-watching, there was no great need to verbalise this knowledge.

I define the concept of *learning-by-watching* [1] as learning through *visual* observation, while *learning-by-observation* [12] is a more holistic and generic concept involving observation with all of the senses. Thus, watching is the most important sense in use when learning to design – a mainly visual practice. This facet distinguishes it from music, where I suppose learning-by-listening dominates over watching. I think we have paid too little attention to learning-by-watching in design education at all levels, and we should better exploit its potential.

I do not see *learning-by-watching* as a contradiction to Schön's highlighting of coaching. In his books, *The Reflective Practitioner* and *Educating the Reflective Practitioner* [15, 16], Schön's major case was actually a design *learning* situation more than a design *practice* situation. In it, the architecture teacher ('Quist') was a senior practitioner coaching an architect student ('Petra'), a junior practitioner in a design studio. In this design learning context, Schön primarily focused on *verbal* coaching, and the architect teacher's visual drawing was secondary. My contribution is to extend the theoretical concepts of practice and *learning* for the reflective practitioner. Learning as *watching* is important. Learning-by-watching is also important *within* learning-by-doing, allowing you to watch what you are doing yourself, experience what you do and reflect on it.

As mentioned, John Dewey's concept of learning-by-doing has been misinterpreted because authors obviously have not read what he actually wrote about it. Ken Friedman makes a similar observation about the concept of tacit knowledge:

> One example of this is the confusion concerning tacit knowledge that emerged as designers became acquainted with the term articulated by Michael Polanyi (1966) in *The Tacit Dimension.* Once again, ignorance and the failure to read are at fault. Proposing tacit knowledge as the primary foundation of design research reflects a surface acquaintance with the concept of tacit knowledge, and it is generally put forward by people who have not read what Polanyi has to say about research [13:154].

Here, Friedman is referring to tacit knowledge connected to design research and not to design education, but I also think many teachers in design have not read Polanyi's writings either. I see learning-by-watching as the way people have learned tacit knowledge [14] visually as reflective practitioners [15, 16] since humankind started to design and make things. However, we have not developed theories about this phenomenon, as we have not been conscious enough to benefit from it in design education. Maybe because it is too obvious to design educators?

I also see learning-by-watching as a broadening of Etienne Wenger's learning theory of *communities of practice* [3]. Wenger, however, did not mention *how* the members of a community of practice actually learn. I regard learning-by-watching to be a crucial way of learning within a community of practice, particularly within a visual field like designing. In a more audio or ear-minded field like music, I would regard learning-by-listening as most crucial. Both learning by *watching* and by *listening*, I would call *observation* with a generic term – learning-by-observation.

3 LEARNING-BY-WATCHING AS A REASON FOR CHOOSING PROFESSIONAL HIGHER DESIGN EDUCATION

Watching seems important in learning vernacular design [1], but the question here is whether and how watching is important for choosing higher design education. In a pilot study for the future research project Design Literacy, we created a questionnaire by QuestBack in 2011. It was sent to all of the novice first-year university students at three different institutions of design education in Norway: the Institute of Product Design at Oslo and Akershus University College, the Institute of Design at Oslo School of Architecture and Design and the Department of Design at Oslo National Academy of the

Arts. The students were not asked, ‘How did you learn to design?’ but rather, ‘Are there any particular experiences, events or people that have motivated you to choose this program?’
One of the students provided the following answer:

> I was at a design fair when I was in upper secondary school. There, Merete Nes showed images of her process and discussed her diploma thesis at AHO. And then, she told what projects she had worked on after she had finished school. This is many years ago now, and there was not as much talk about design as nowadays. Therefore, I had never heard of industrial design. When I saw the hand-drawn sketches of a toothbrush Merete had made, I knew what I was going to be and where I should take my education (My translation from Norwegian).

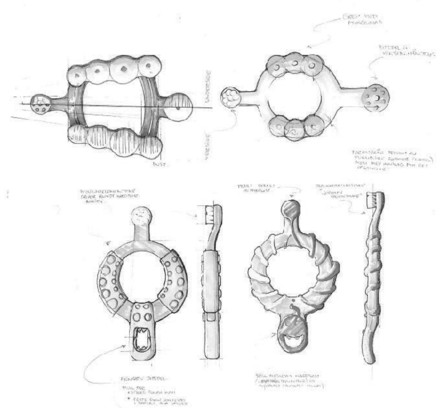

Figure 1. The toothbrush Merete Nes drew and designed

Figure 1 shows hand-drawn sketches of a toothbrush made by Merete Nes. The student’s comments show that she had not even known about industrial design before she saw these drawings from the degree programme in industrial design. Often, a designer or artist is a son, daughter or grandchild of a designer or artist. Of course, this phenomenon could be due to inherited capabilities, but more likely, I think *watching* family members make something could influence the younger generation.
When we asked novice design students about this questions, they gave the following examples:

- Mom with my upbringing with design and sewing - and not least knowledge…
- My grandmother and uncle are artists, Mom has always regretted that she did not choose a more "creative" profession.
- There’s not a craft we did not make at home: felting, painting, clay, embroidery, knitting, sewing, carpentry, you name it!
- Thanks to my mom, I have always done needlework, sewing and design.

Though the questionnaire was a pilot for a larger future research project about design knowledge from kindergarten through PhD studies, it showed that watching plays an important role in various contexts. None of the asked novice design students mentioned watching design teachers practicing at primary or secondary schools as a decisive factor for choosing professional design education. All of the students that mentioned watching others designing, told about family or professional designers, not design teachers. Could this finding indicate that design teachers do not show the young design students in primary or secondary school how to design?
What traditionally has been regarded as learning [8] involves students listening to a teacher who orally explains a phenomenon (speaking to the whole class or to a single student), perhaps supplemented by writing on a board or drawing a sketch or map. These activities are intended to have a pedagogical purpose; they are not considered to be activities for their own sake. From my experience, these activities were rare for teachers in arts and crafts education, called Forming, in primary and lower secondary school in Norway from 1960 to 1997. Forming merged the subjects of drawing, textiles and woodworking [9]. In Forming, learning-by-doing often was the ideal, and the misunderstanding of the concept went even further, in my opinion. It often just meant *doing*, with the learning left out –

reduced to activity, as Dewey and McLellan pointed out. In Forming lessons, students were encouraged to express their inner feelings, influenced by the romantic theory of Viktor Lowenfeld [10], stressing the natural growth of children's drawing without disturbing teaching. There was nothing to learn, even by doing; students just needed opportunities to express themselves. One result of this doctrine was that teachers never demonstrated or instructed, and students rarely watched any samples, models or patterns, nor any artefacts or processes. To a certain extent, the influence of this view on learning-by-doing still exists in the current Art and Craft subject. Indeed, the importance of learning-by-watching has been overlooked in this mainly visual subject. I think the same is true in professional design education; even there, a more conscious way of learning-by-watching could be developed.

In order to develop a better understanding of how design is learned and practiced in general (design thinking), I hope that these interpretations can contribute to an adaptive theory about the practice and learning of design – with a focus on learning-by-watching in a reflective community of practice [11]. To fill the rather vast holes in this patchwork of design research, I have suggested herein some research 'patches', some stitch work, that I regard as particularly important for strengthening and developing the fabric of design learning in the future.

4 CONCLUSION

In this paper, I have critically discussed my concept of learning-by-watching, defined as learning through visual observation, in connection with Dewey's concept learning-by-doing. I have also presented and discussed learning-by-watching as a reason for choosing professional higher design education based on a questionnaire of novice university-level students in their first year at three different institutions of design education in Norway. The research concludes that watching family and professional designers seems to be an important factor in this decision, but none of the students mention watching design teachers at previous schools as a reason for choosing professional higher design education. This finding could indicate that design teachers in Norway still follow the Forming doctrine, where showing students how to design was almost forbidden.

Perhaps further research will demonstrate that learning-by-watching is a more important part of professional design learning than design educators realize today.

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SYSKIT 2.0 – IMPLEMENTATION OF A SYSML TEACHING APPROACH AND OBSERVATIONS ON SYSTEMS MODELLING BY MECHATRONIC TEAMS

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ABSTRACT
To fulfil the demands of modern product development processes, nowadays engineers have to interact with the domains of mechanical, electrical and software engineering. Due to this, their day-to-day business in practice is strongly characterized by working with different departments and stakeholders out of different disciplines. For improving their communication and to build up a common understanding, an interdisciplinary model language is needed. The Systems Modelling Language (SysML) is a language for modelling these interdisciplinary technical aspects of a system. This paper introduces the revise of an educational teaching approach for SysML presented in 2014 [1]. It is called SysKIT 2.0. First findings on the learning experience and the modelling results will be presented in this paper. The current approach was taught for the first time in a multidisciplinary course, where the students have lectures, exercises and a development project. In their development project the students have to use SysML for modelling – concepts, prototypes, validation and optimization. This paper presents the revised concept of SysKIT. The modifications compared to the first published concept are pointed out and explained.
Further the paper analyzes the modelling techniques of different students groups and summarizes statements about the benefits. These findings were made by interviewing and observing the SysML-trained teams using SysML during the development project.

Keywords: Mechatronics, SysML teaching approach, systems engineering, modelling method, project based learning.

1 INTRODUCTION - JOB PROFILE OF MECHATRONIC ENGINEERS

The innovative capacity and highly developed systems and products are a key factor for Europe's leading economic position. The demands on today's product developers are rising and it is getting harder for an individual to keep an overview on the whole product development process. For success in today's development projects, engineers have to apply knowledge of the fields of mechanics, electronics and information technologies. Their daily business is strongly affected by working in interdisciplinary teams of different departments. Thus joined-up thinking and interdisciplinary comprehension are required [2]. Students in mechatronics are setup to educate engineers to fulfil these demands. It is expected from mechatronic engineers to have a broad general knowledge and detailed knowledge, in a field of specialization. This knowledge should be applied together with methodological expertise to solve complex problems by finding innovative solutions. New processes, systems and products should be designed by using mechatronic synergy potentials. The survey 'Faszination Konstruktion' (engl. fascination engineering design) - from the national academy of science and engineering Germany - points out the need for so called system engineers that possess knowledge in the fields of mechanical, electrical and information engineering, manufacturing and assembly techniques, project management and creativity techniques [2]. As published by Matthiesen et al [3] a curriculum for mechatronic engineers has been developed at the KIT. Within the fifth semester the students will attend a course *development of mechatronic systems and products*, that consist of lectures, exercises and a development project (see chapter 2). In the lectures and exercises the students learn the SysML basics and apply them during their development project. SysML is used as a common modelling language to support the system design and communication. The graphical modelling language SysML is for general purpose and supports the analysis, specification, design and validation of complex systems. [4] The visual modelling during the development process helps to build up a better communication and increased system knowledge of all project team members. Diagrams could also be used to communicate with stakeholders and customers. [1]

2 THE SYSKIT TEACHING APPROACH 2.0

This paper introduces the revise of the educational teaching approach for SysML presented in 2014 [1]. The new version is called SysKIT 2.0. The modifications compared to the first published concept are pointed out and explained in chapter 3. The approach was first tested in a pilot study (1 day workshop with 15 participants), modified based on feedback and findings out of the study. It was taught for the first time in the multidisciplinary mechatronic course (*development of mechatronic systems and products*) in 2014 at KIT. The revised SysML teaching approach consists of two levels (Figure 1) and is structured according the Bloom taxonomy levels [5]. In the course the students have SysML lectures with integrated active exercises. During the lectures the difficulty of the exercises, is increased from lesson to lesson adequate to the students' level of knowledge.
In the same course they work on a development project to develop mechatronic systems under realistic industrial conditions and use SysML for modelling [10].

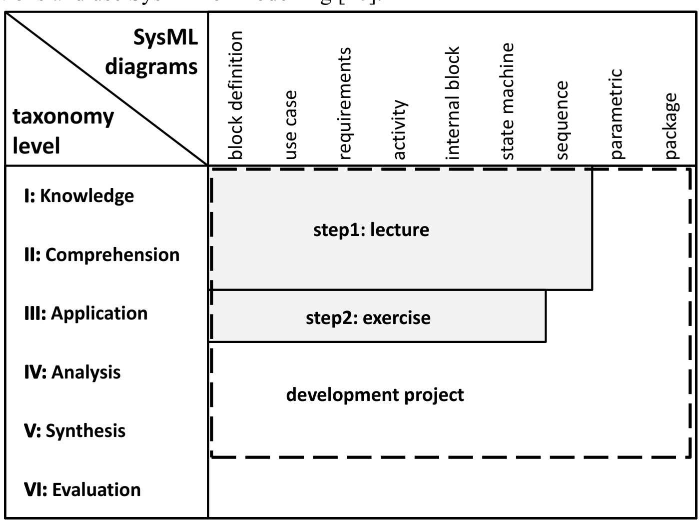

Figure 1. SysKIT 2.0 - a two step SysML teaching approach

Introducing lecture: This phase introduces SysML and model based system engineering to the students. During the introduction the participants are taught on knowledge and comprehension of most important SysML diagrams and the basic elements for each diagram type.
Exercises: After introducing one diagram and the possible elements, there is an exercise for each diagram type with worksheets. To reduce the complexity in this very early stage (application, not analysis or synthesis), most of the model contents are given. By doing so the students apply the new elements. After 10 minutes of partner work a possible solution of the exercise is presented. They focus on modelling SysML and are not distracted by technical complexity.
The lecture hall sessions (introducing lecture & exercises) prepare the students to use SysML in their development project. The goal is to reach the taxonomy level III – application of SysML (see Figure 1). In the development project the students have to develop under nearly industrial conditions. SysML supports the teams to get a common understanding and a better structured development process. A correction and discussion of their models is conducted in three workshops with supervisors during the semester. As shown in [1] the SysKIT-approach is designed to resolve the deficiencies of other SysML trainings: (1) overstraining caused by too many new elements at the same time, (2) overstraining caused by unknown tool, (3) dissatisfaction caused by missing a sample solution (4) frustration caused by not recognizing the benefit of using SysML.
How these dissatisfactions will be handled in this approach will be discussed in the next sections.

Sequential modelling in lecture hall sessions: To resolve deficiency (1) the SysKIT lecture introduces new diagrams & elements step-by-step (sequential) and the newly introduced diagrams are practiced in an exercise session before introducing the next diagram. This step-by-step-modelling is very uncommon for industrial projects, but it is a very effective way to get students familiar with SysML. Teaching assistants support the students by answering questions and discussing modelling options during the exercise sessions. Usually in industrial projects a designer adds contents to the different diagrams iteratively as the information (requirements, behaviour, structure, etc.) occurs. Figure 2 illustrates the differences between sequential (lecture hall sessions) and iterative (project work) modelling. The differences between this two modelling techniques are discussed with the students.

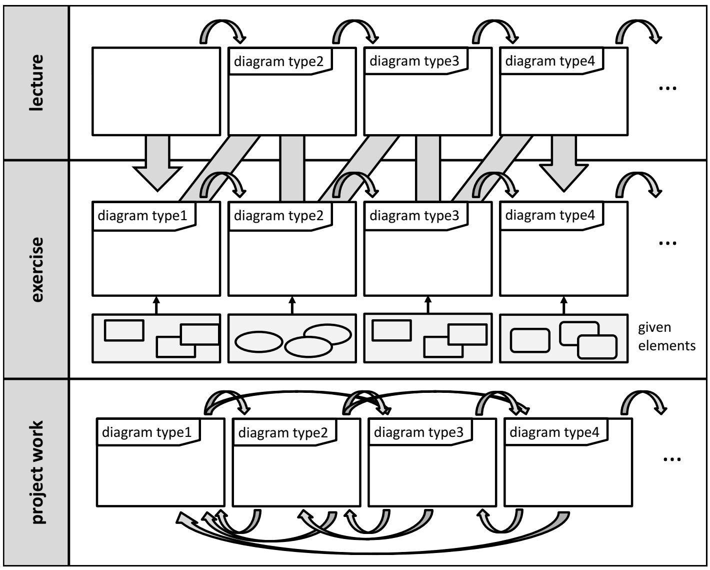

Figure 2. Process of the SysKIT 2.0 teaching approach

No SysML software modelling tool: During the exercise the students start with individual pen and paper modelling. This reduces the difficulty compared to learning a software modelling tool at the same time (2). To support modelling during the development project the teams can use whiteboards and memox©-cards. These cards are made to develop together in a team as shown in Boes [7]. The main benefit is, that cards can be rearranged easily to create clusters or describe dependencies. Furthermore, the content written on the card can be added, changed, or erased during the usage. For a better documentation and presentation the students can redraw their models in MS Visio with the SysML shapes of Pavel Hruby [8].

Discuss an example solution: A very common problem of modelling with SysML is that there is more than just one correct model. With regard to a given objective, one model appears more appropriate than others. This can lead to confusion (3) and dissatisfaction of the students. To resolve this deficiency, at the end of each exercise phase a given example solution helps to reflect and discuss the exercise together.

Point out benefits: During the lecture the benefits (4) of SysML such as a better system knowledge by interconnected model elements are pointed several times. Further on the methodical importance of generating and tracing requirements during different development steps are discussed.

Given elements: In many other SysML teachings the participants have to analyze a technical system e.g. a coffee machine and model it. It was observed that modelling beginners focus more on the (interesting) technical content than on the modelling itself. Thus time consuming discussions about the system instead of discussions on modelling took place in other SysML courses. When model content is given these discussions are obsolete and the students can focus on the modelling itself. This is another important aspect to speed up the learning during the very time limited lecture sessions.

3 SUMMARY OF CHANGES FROM SYSKIT TO SYSKIT 2.0

There are several changes and improvements made since SysKIT was published. These changes were made based on findings of the pilot study and findings made during the final preparation of lesson material (power point slides, worksheets, handouts). The most relevant changes are:

Steps: As part of the course *development of mechatronic systems and products* the SysKIT approach is reduced from a three step into a two step approach. The study made clear that the abstract modelling is even more difficult and time consuming than modelling a simple system.

Duration: Due to time restrictions the SysML teaching was conducted in five lecture hall sessions of 90 mins each instead of a two-day workshop. The intensive practicing of modelling with SysML is part of the development project. During office hours the students can discuss questions regarding SysML.

Modelling process: A reference modelling process has been developed to support the students with an overview of all modelling activities. Figure 3 shows the process as a SysML activity diagram. This process is based on the modelling process taught at HAW Hamburg from Abulawi [9].

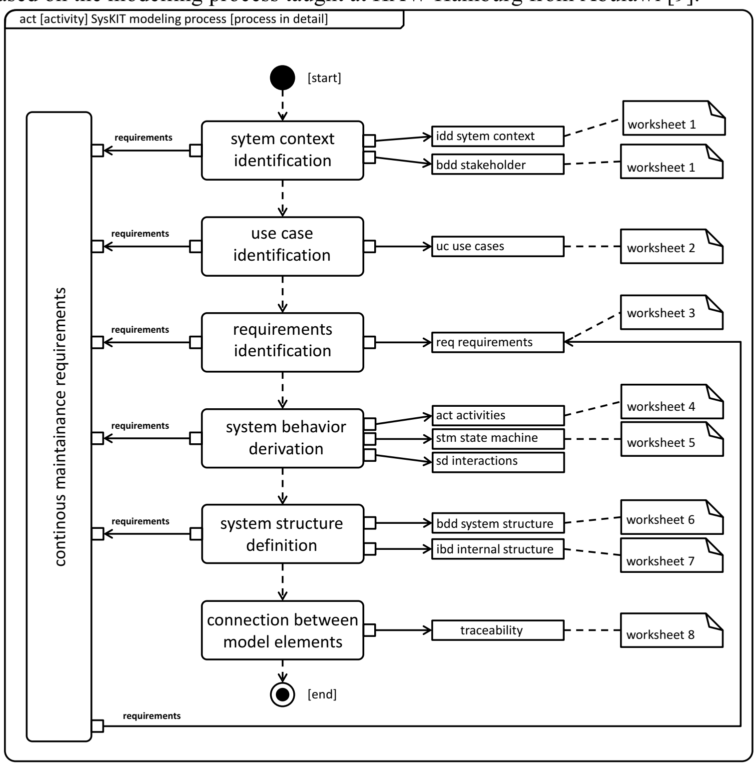

Figure 3. SysKIT modelling process

4 SYSTEMS MODELING OBSERVATIONS BY MECHATRONIC TEAMS

As mentioned above the students get knowledge (I) and comprehension (II) of SysML in lectures, they apply (III) their knowledge in exercises and analyze (IV) and synthesize (V) a system using SysML in a development project under realistic industrial conditions. In this development project, the students develop concepts, build prototypes and conduct validation and optimization activities. To support all these activities they build up a common understanding by modelling with SysML.

One of the key elements of the development project is cooperation – for the final succeeding – two groups have to work together very closely as one team [6]. Thus, each group is responsible for its own subsystem, but to achieve the shared goal, the team has to continuously discuss, negotiate and decide about the requirements and constraints for the overall system, resulting from their jointly pursued strategy. During the lecture hall sessions it was recognized that it took a couple minutes for the students to switch from lecture to exercise and get familiar with the new task. At the end of the exercise sessions student questions were still left. The following findings were made during the development project: It was observed that modelling with SysML achieved very good common system knowledge throughout the teams. All teams used the memox©-cards to start modelling with all team members. The discussions while modelling helped to find answers for questions like: '*What aspects of the system context are relevant for our development*?', '*How important is a certain requirement*', '*How do we structure our system?',* '*How is the order of actions in our strategy in detail*?' Especially modelling the strategy with activity diagrams was a big benefit. After modelling on whiteboards the diagrams have been redrawn with MS Visio. These diagrams (more nicely than photos of handwritten whiteboads/memox©-cards) are used for documentation purposes and have been changed if any new findings required so (compare Figure 4). This ongoing model updating as not observed on all diagrams. Since no modelling software was used, a high effort would have been necessary to do so if an element was changed which is used in several diagrams for example. Finally the diagrams have been used to communicate and discuss the project results during the workshops with supervisors.

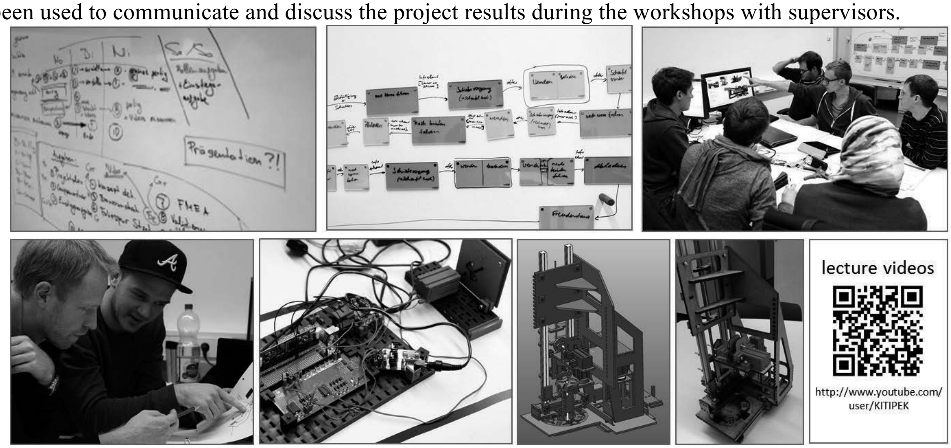

Figure 4. Observation of mechatronic teams during the development project

During the discussions with the teams it was observed that interfaces between the cooperating systems and system structure have not been modelled very in detail. A lot of information was saved in spreadsheets, text documents (as part of meeting minutes) and mostly in visualizations such as sketches, detailed drawings and CAD models. Without the knowledge of a single team member it would not have been possible to navigate to these information sources from the system model. Further on some information were not documented, but were available upon request from mind. Further on it was noticed that some more elements should be introduced in lecture. Especially elements to model more complex loops and exceptions in activity diagrams were requested by the students to model adequately for a good preparation of control strategies. Some students have been able to look up possible elements to do so by their own. Others modelled only with the elements from lecture. Thus the models were imprecise, but the teams knew that the model didn't exactly reflect what they have been developing. Some students hesitated to state that modelling had a benefit for them It was observed that this was influenced a lot by (1) missing connections between the elements, (2) by missing a real traceability (beside the drawn arrows) and (3) by missing an auto update of one element in all diagrams if changed in one diagram. This impression resulted from not using modelling software. Students stated the willingness to learn and use modelling software:

> *'A SysML software tool would have helped us to realize the benefits of traced models and could save time because of the reuse of elements.'*

At the end of the course there was an evaluation and the students were asked, if they like the structure of the SysML teaching, order of introducing the elements and the mixture of lectures and exercise. Nearly all students enjoyed the course and would keep the concept as presented in this paper. Some minor potential for optimizations have been stated. Most important was that the students wished to get the SysML lecture and exercises earlier in the semester to start modelling in their development project at the beginning. A judgment on the benefit of using SysML in mechatronic teams is not possible, since the effects of not using modelling software have been severe (see above). A subjective overall judgment on using SysML is positive because it helped a lot to gain common system knowledge and to communicate project results.

5 SUMMARY

This paper introduces the revise of the educational teaching approach for SysML presented in 2014. The approach was tested in a pilot study, modified and taught for the first time in the multidisciplinary mechatronic course with 40 students. The new version is called SysKIT 2.0 and the modifications compared to the first published concept were pointed out. The new SysML teaching approach consists out of the two steps and is structured according the Bloom taxonomy levels. In the course SysML teaching is conducted during lecture hall sessions and further practicing of SysML modelling was made during a development project under realistic industrial conditions. The students built SysML models of their mechatronic systems, which helps to build up a better communication and increased system knowledge of all project team members. Nearly all students recognized the benefit by using SysML.

6 OUTLOOK

During the SysML lectures and by analyzing the development project some potential for further optimization for the next class were found: (1) SysML will be introduced one week earlier in the course curriculum, so that SysML modelling already supports the early needs of the development project. (2) Additional elements for modelling loops and exceptions will be introduced. (3) Due to the fact that the number of student will rise to approximately 100, more assistants for answering questions will be needed. (4) To be more time effective during lecture hall sessions there will be an exercise stage after every second lecture stage but doubled in time. So there will be less changes between lectures an individual work of the students and more time to answer all questions. (5) To experience the main advantage of model based systems engineering compared to document based engineering (traceability, interconnected models, etc.), a software modelling tool will be introduced. The effect of tool based modelling compared to pen and paper modelling will be observed and published.

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CHOOSING AN APPROPRIATE DESIGN PROCESS BRIDGING THE KNOWLEDGE GAP BETWEEN PROFESSIONS AND PARADIGMS USING VON HIPPEL'S END USER THEOREM – A CASE STUDY

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ABSTRACT
Thorough understanding of end user needs is often considered a necessity for achieving success when engineers are designing products. Taken to extremes this approach requires the engineer to be an attentive, critical and creative end user before success is obtainable. This is naturally not possible, never the less the issue is especially relevant in relation to the education of engineering students when doing product design aimed at an unknown territory. In this paper, a guideline for doing product-design in close cooperation with non-technical end users is outlined. The procedure is based upon the Von Hippel End User Theorem, although the setup also addresses the steps prior and subsequent to the use of the theorem. From a didactic perspective, the student is forced to acknowledge "non-engineering" views and values and their importance for the product design. This paper is based upon observations gathered through a project at the final semester of the Mechanical Engineering Education at VIA University College in Horsens, Denmark.

Keywords: Engineering for alien environments, Von Hippel End User Theorem, prototyping, product design methodology, product design education.

1 INTRODUCTION

Product development in product design education is a practice-oriented discipline focusing on efficiently achieving goals through the optimal choice and use of methods for the task given. The combination of a decreased average product lifetime and the opening of markets makes the task of delivering "the right product at the right time" continually harder to achieve. From the perspective of the development engineer, mutual considerations to various parties and stakeholders must be taken, with focus on meeting the demands of the end user. Although numerous methods for uncovering the needs of the end user has been introduced over the years [1] the engineering task is becoming more multifaceted thus making the product design discipline more experience based. The challenge is therefore: How to educate novel engineers to operate fast and efficient when developing products for a use and working environment they are unfamiliar with?

Using the Von Hippel End User Theorem (VHEUT) [2] as a method for the interaction between students and end users provides a short cut to understanding user needs while at the same time making the student aware of own professional identity. This includes identifying "black spots" of deficiencies when interacting with alien professions having a different mind-set and professional values compared to the one of the engineering world.

In this paper, we describe how an introduction of VHEUT to a small group of engineering students enabled them to gain user inputs for the first phases of a product development project, using the input to reveal needs and choose between multiple solutions in an iterative and continuous dialogue with the end users. The procedure involved the students doing prototypes and defining a workshop session with the purpose of end-users executing "on the spot" improvements of the prototype. Furthermore, the students were responsible for the planning and communication with the end users' organisation. By utilizing this method, the students managed, in cooperation with the users, to develop a novel product concept paying attention to important yet non tangible end user requirements while at the same time being in accordance with "good engineering practice" in terms of mechanical stability and produce ability. Based upon our observations a guideline including areas of attention, for applying VHEUT in engineering student projects is listed in this paper.

2 BACKGROUND

The Mechanical Engineering education at VIA University College is a bachelor education using Problem Based Learning (PBL) [3] and project based group work as one of the backbones throughout the education. The education is international with a student mix of approximately 1/3 Danish and 2/3 non-Danish students, the latter mainly having heritage in Europe all though students from all continents usually are present. From third semester, all lectures are taught in English[4]. The last semester includes the Final Bachelor Project covering a budgeted workload of 20 ECTS equivalent to a workload of 550 hours of work per student. The students are encouraged to form groups on their own as well as choosing subject for their final project. The assigned supervisor also acts as examiner when the project is evaluated at an oral examination.

2.1 Project setting

The urological "Ward 8" at the regional hospital of Viborg employ a staff of approximately 30 professionals with a majority of nurses. A common treatment is cancer surgery in the prostate. After surgery, blood from the operated areas flows to the urine bladder were it coagulates into blood chunks (clots) causing severe pain. Standard procedure for removing the blood chunks is a two-step process done by the nurse staff. The procedure comprises the injection a salt-water solute with a 50 ml syringe into the urine bladder through a catheter. The aim is that the salt-water dissolves the clots. These are then removed through the catheter by suction with the syringe. The procedure continues until the nurse determines that the level of blood in the bladder is acceptable. This is done by comparing the extracted solvent with a printed colour scale. The process is questionable from various aspects: ergonomic, hygiene, ethical and risk. Furthermore mastering the procedure is a taught competence gained by letting experienced nurses train newcomers in a peer training process normally of a 2-3 week duration.
Mastering the procedure is best described as craftsmanship-competence based upon practical experience and "feeling". This approach turns the procedure into a dogma, making the nurses focus on the patient treatment by mastering the procedure – no questions asked.

2.2 Challenge

The concrete product development challenge was therefore for the students to design a novel urine bladder rinsing device that could address the various aspects (ergonomic, hygiene, ethical and risk) of the existing solution. However, as the existing solution/procedure to a large extent is a craftsmanship competence, the *real* core challenge was: "How to do product design regarding a need that in its essence lack identification from the end users nor is easily tangible in engineering terms?"

2.3 Framework / Context

The task was assigned to a group of two students wishing to do their Final Project within the specialization framework "Innovation & Product Design" [4]. The students had different nationalities: Danish and Rumanian, and had not been acquainted prior to the project start. From start to hand-in, the project period lasted 22 weeks.

3 METHOD

3.1 Project set-up and execution

After an introductory visit to the hospital, it was decided to incorporate the use of prototypes in the overall project run set-up. The reason for this was the assumption that a functional model would be a necessity for obtaining effective means of communication with the involved nurses. From the beginning, the students realized that the difference in mind-sets and profession was so big and alien that ordinary written and oral communication would fall short. The execution of the project followed the plan illustrated below (Table 1) – however iterations were foreseen from the beginning.

Table 1. Time Perspective

Phase	Duration (weeks)	Activities	Considerations
1	4	Defining the task Understanding needs: Interview with nurses Setting up requirement specification Defining market size and prize Setting up product assessment matrix	As stated earlier, the overall concerns of the existing procedure were stated at a high level thus being rather difficult to transform to measurable quantities for the subsequent solution. Instead, the requirements to the solution were rated against each other in order to define the priorities to the solution See Table 2.. Market size estimation was done by extrapolating the need at the ward into a national perspective.
2	2	Idea generating – product concepts.	On basis of the previous phase, conceptual solutions were generated.
3	1	Session with end users - Nurses choosing solution	A session with the end users was executed discussing pro and cons of each of the product ideas and rating them against each other's based upon the priorities set –up by the end users.
4	2	Prototype manufacturing	The manufacturing of the prototype was done by the students utilizing tool shop and a 3D printer.
5	3	Preparation & execution of End User workshop based upon VHEUT	The workshop was done in three sessions the same day with different groups of nurses all from the urological ward. Each session was recorded with a wide-angle HD camera.
6	10	Product development based upon the previous phase and Report writing	

Table 2: End user priorities

Consideration	Rank	Weight in percent
Hygiene	1	20%
Ergonomics	2	15%
Process time	3	15%
Risk	4	14%
Training	5	10%
Evaluation of waste water	6	10%
Ethics	7	10%
Disinfection	8	3%
Price	9	3%

By revealing and discussing various solutions with an end user committee early in the project, the above design parameters were defined (Table 2). From an engineering perspective, the assignment at first glance appeared to be an obvious automation and control task; through a "pump and a processor solution", the nurse in charge would merely have to mount and detach the equipment leaving the rest to the machinery. This suggestion was instantly rejected by the end user committee. The reasoning is perceived to be as follows: Nursing education is built upon a combination of medical theory and empathic approach gained by training through practical placement sessions thus becoming a craftsmanship discipline. A solution implying extended automation would distance the nurses from the procedure thus diminishing their ability to execute their empathic skills. The example also illustrates a typical engineering "Blind Spot": Neglecting relevant parameters not being part of the classical engineering identity (for instance empathic relations).

Adequate product requirement information cannot be gathered efficiently solely through meetings and user interviews when concerning "hands on products". One of the authors had the privilege of visiting the ward at several occasions when initially defining the task and later on in the role of supervisor. Through these meetings, a recurrent experience was the rise of new inputs and requests from the users. The essence of VHEUT is the term "sticky information" addressing the condition that relevant user knowledge is unconscious to the end user. Common examples are the ability only to remember a pin code when a keypad is present or explaining the procedures of a software program only when being able to access the commands with the mouse. In order to reveal this hidden information the end users are asked to improve a prototype made with respect to engineering aspects such as manufacturability, costs, etc. From the position of the engineering student, this approach is an effective and reasonable short cut when dealing with development tasks for an alien territory like the bladder rinsing equipment. Instead of spending time and resources, trying to reveal and understand the user needs before commencing the design, the student can focus on exploiting her engineering skills within the boundaries of her profession thus avoiding the trap of dead ends by misjudging user needs. The task for the student is therefore altered into doing a prototype easily changeable/adjustable by a known group of end users, at the same time paying consideration to business, quality and technology. Thus, the purpose of the prototype was to:

1. Assess the value of the chosen overall concept in a "near to real life" environment.
2. Defining (and on the spot adding) overseen issues in the solution concept.
3. Improving details by forcing the nurses to relate directly to the functionality when confronting them with the prototype in a use situation.
4. Also, although not explicitly stated: Ensure credibility and motivation for the subsequent development task.

The prototype used at the workshop looked as illustrated below.

Figure 1. The prototype Mock-up for end-user test

Along with the prototype, a "toolkit" was brought to the workshop. It consisted of tubes, syringes, catheters, urine bags etc. along with a range of common tools like scissors, tape, glue screws etc., all with the purpose of making it easy for the test persons to adjust the prototype on the spot when the need occurred. The workshop lasted one day covering three independent sessions (approximately 90 minutes each) with the participation of teams of 2-4 nurses - all from the urological ward. All sessions were recorded (picture and sound) with a HD wide-angle camera. The workshop took place in a training ward with dummies instead of patients. After a short 5-minute introduction of the prototype and toolkit, the nurses were asked to use the prototype to perform a bladder rinsing procedure on the dummy, and encouraged to modify the prototype using the "toolkit" when needed.

4 OBSERVATIONS AND RECOMMANDATIONS

The workshop made the typical engineering dilemma obvious: When to stop analysing the problem and start developing? The used pragmatic approach succeeded in narrowing the solution area at an early stage postponing the hidden requirements to the VHEUT session. A positive side effect was the early "sell-in" to the end user committee. Incorporating the end user committee in outlining the overall solution at an early stage gained involvement and increased support from the beginning while on the other side bringing the comfort to the students that they apparently were on track. After having mutually confirmed the overall product principle, the next step was preparing the VHEUT session.

Designing and manufacturing the prototype for the VH workshop turned out to be the most unexpected time trap of the project. Luckily, one of the students possessed a machinist degree enabling the manufacturing of the prototype to be done relatively quickly without massive involvement of external parties. Providing the prototype for the end user trial lasted app. 2 weeks.

The outcome from each VHEUT workshop session turned out to be consistent from session to session revealing the following:

1. The operation of the syringe was acceptable in concern of ergonomics and manual power needed.
2. The geometrical size of the system was acceptable.
3. Use of two syringes (clean and waste) was reduced to one in order to simplify the procedure.
5. The setup was modified by prolonging the tubes in order to achieve a "clean" and a "contaminated" side of the system providing the nurse to use one hand for manipulating the catheter and setting the valve while operating the syringe with the other hand.
6. Two of the three groups questioned the possibility of achieving the required level of sterility of the device.

All in all the workshop was considered a beneficial instrument in improving the overall concept, or as the students wrote in their report:

> *"Overall, the workshop was a very great success in many ways. First of all, it was very satisfying to see that all the nurses that tried the prototype gave a positive feedback and they believe in the usability of such a device, everyone saw it as an improvement of the today's method of bladder flushing; in relation to the problems, the old procedure leads to."*

Although the procedure of the VHEUT is rather simple to comprehend for the students, based on our observations, we would like to propose the following guideline, including areas of attention, for applying VHEUT in engineering student projects:

4.1 Defining the relevance of VHEUT for a given task

The following questions could indicate the relevance of VHEUT for the given task.

1. Is the product in question used by persons with an "alien" professional education and attitude?
2. To which extent is successful use of the product based upon a tactile experience?
3. Is access to relevant end users provided for, and are they motivated for change and participation?
4. Are the identified end users able to spend the time needed for participating in the workshop?

Obviously the answer to the above needs to be a "yes", however setting up exact conditions for this is a more complicated matter that needs to be defined in relation to the specific development task. Based upon the referred project it is the impression of the authors that question 1) seems to be the one easiest underestimated. We therefore claim that unless the students / product designers can describe themselves as end-users, performing a VHEUT with third parties is of relevance.

4.2 Check list for students when preparing a VHEUT

Prior to preparing the workshop, the students need to define:

1. What outer boundaries are set up for the solution (e.g. cost, size, legislation etc.)?
2. How can details in question be prototyped in a way that is easily changeable by the users?
3. Do not overdo the prototype – make it express need for improvements.
4. What is possible to achieve within the time-frame of the work shop?

3) From the case-study it was revealed that engineering is just as alien to nurses as nursing is to engineers. In order to avoid misinterpreted respect, it is important that the prototype's level of finish encourage the workshop participants to make improvements. Despite its unattractiveness of the manufactured prototype, the functionality of the moving parts is at a level where relevant feedback can be obtained. This approach should on the other hand not been taken to extremes resulting in the end users feeling professionally offended.

4.3 Check list for students conducting a VHEUT

One simple rule seems to be sufficient, however, of great importance:

1. Students must shut-up and observe!

Revealing own creations towards a third party can be a self-exposing experience for most students. Excuses, explanations and suggestions causes bias during the workshop (but are welcome later). Therefore, the students need to let the end users execute the workshop without interference. The fact that the workshop was conducted in Danish and one of the students was from Rumania allowed the latter to concentrate on doing observations directly on the progress without being disturbed by the discussions of the nurses (and the interference of the fellow student).

4.4 The role of the supervisor in student projects involving VHEUT

The role of the supervisor in the described project required a more proactive approach than usual:

1. Inform the costumer about what to expect of the outcome.
2. Quantify investment and deadlines for the end users.
3. Be prepared to facilitate the students on "fluffy" non-engineering matters.

1) When dealing with end users not familiar to engineering and engineering procedures, a mutual balancing of expectations is a necessity for successful cooperation. In the described case-study it was agreed that the outcome of the project should be a concept suitable for a take-over by a third party – however no guaranties could be issued. Furthermore, the project's placement in the curriculum needs pointing out to the end user. The documentation part of a student project consumes a rather big amount of the total project, thus likely to give an impression to the end users that development has stopped at the expense of rather unnecessary report writing.

2) The customer being a ward at a public hospital meant that focus was set on a time budget already under strain. Even though the face-to-face sessions were minimized, planning and correspondence at times seemed weary for the students. Setting up a single point of contact was beneficial, however, it is suggested that maximum response time is defined from start in future projects.

3) From experience, engineering students tend to focus on the "beauty of the technical solution" more than the practical efficiency of the solution itself. In the case study, the disappointment when the nurses chose the technically simplest version of the proposed concepts was unambiguous. An effort in retaining the overall purpose is therefore an aspect that the supervisor needs to be prepared for.

5 CONCLUSIONS

Based upon the case study of the student project, the authors conclude that used properly, the Von Hippel End User Theorem is a relevant and efficient method for enabling engineering students to act efficiently in "unknown territory" while simultaneously gaining awareness of own professional identity including implicit gaps. We propose a guideline for incorporating the Von Hippel End User Theorem in context of student projects within Product Design Engineering. From the case study and our observations, we have seen that using the proposed guidelines, students will be able to enhance a product, incorporating end user needs, thereby bypassing the traditional investigations of end user requirements. The authors envisage that the procedure described in this paper is transferable to a wide range of engineering tasks when involving end users with unfamiliar cultural and professional background. In perspective, the authors propose more research in this area, for instance how the guidelines can be adjusted to take the end-user / lead-user perspective into account.

ACKNOWLEDGEMENTS

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THE MATERIALITY OF COLOUR IN DESIGN EDUCATION: FUNCTIONAL CODES AND CULTURAL CONTEXT

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ABSTRACT
Colour competence is often seen as a basic knowledge introduced in the early stage of product design education. A knowledge gap was identified that required more advanced learning outcomes for colour in curriculums of product design education at master levels. How can colour knowledge in product design contribute to corporate social responsibility? This was explored through a case study approach. The first case study was a master student's development of various bottle-green glass lamps in collaboration with the glass industry. The second case was the development of shades of blue in a ceramic colour surface used in public art in a chapel of rest. The third case was the use of signal yellow colour to demonstrate interface areas in an offshore context in the oil industry. The implementation of all solutions concerned both technical challenges and people's emotional experiences of what was meaningful in each context. The learning outcomes of the study were an expanded understanding of how colour can be substantial in certain contexts. The first was that knowledge about technical premises in materials was needed to design colour surfaces. The second was that ethnographic competence was needed to analyse possible emotional experiences of colour in various cultures. The third was that competence in product semantics is needed to implement a coherent use of colour as indexical signs in health, environment, and safety.

Keywords: Colour technology, ethnographic methods, corporate social responsibility CSR, master education.

1 INTRODUCTION: BASICS OF COLOUR IN PRODUCT DESIGN

Colour competence is often seen as a basic knowledge introduced in the early stage of product design education. Colour as a phenomenon, however, is complex and has, in the classical studies by the scientist Goethe [1] and later the artist Albers [2], been explored through advanced practical experiments and physical experiences. Through such empiric experiments, they demonstrated practice-based principles of colour competence that can be transferred into the more advanced tech-based training courses in the field of design. In spite of this, their theories seldom have been implemented as learning outcomes in master levels of design education, although the Bologna process requires that formulating knowledge should be done with regard to learning outcomes [3]. There is therefore a need to develop more advanced learning outcome formulations for design students at a master level, informed by relevant theory and professional design practice.

2 BACKGROUND: EXPLORING COLOUR IN PRODUCT DESIGN

Colour can promote corporate social responsibility (CSR), creativity, and innovation in design and engineering, because according to Karjalainen, the visual appearance and the semantic signs in the design of a product are closely connected to the strategic branding of a company [4]. Colour is frequently mentioned in regard to learning outcomes in introduction courses at a Bachelors level but rarely at a master's level.

One of the few examples was a Swedish study that explored colour as the main approach in product design for Bachelor students in the 3rd year and Masters in their 1st year [5]. They explored the concept Identity Tool Kit (ITK), a method that aims to assist designers and contractors in meeting on "visual platforms" in relation to the development and production of products and services, and started from point 4 of the ITK method, "Shape & Colour". The aim of the research was to find a method to represent the complexity of the relationship between colour and shape, in the specific context of the design of product or service. This was in order to make possible communicating this parameter during discussions in a team of professionals or to the end user, and to be further adoptable in design education. They found that the students that participated in the workshop showed enthusiasm and true passion and succeeded very well in their task.

2.1 Colour identified as learning outcomes

However, although much experimented with in practice, there have been few learning outcomes that are mentioned specifically at Masters level in product design, although learning outcomes in education should be identified and formulated in curriculums for all three cycles, according to the Bologna process [3]. It is even less described as a learning outcome in PhDs in Design & Engineering. A reason to focus more on the phenomenon of colour in product design education is that colour engages both students, teachers customers and mass media in visual culture in practice, so how to integrate colour as an explicit element in projects and problem based learning should be further discussed [6]. Colours are connected to people's lives in various ways. According to the social anthropologist Taussig, colour appears in different ways in the community, both in culture and working life [7]. He promotes the fact that colour is important because it is attached to people's feelings, their social rituals, and cultural codes. Further, he claims that to understand colour it should be seen as much more than a technological issue or trying to reduce it to a simple colour code, as it is associated with the experience of people's physical surroundings, social behaviour, and their way of expressing themselves. For a product designer it is essential therefore, to be able to relate to the complexity of colour parameters, and to have competence that exceeds the basic colour theories.

2.2 User experience

One of these competences is to expand the understanding of user experience of a product in the environment. Thus the aesthetic experience connected to colour in design products is essential [8]. A social dimension is the challenge to motivate people to accept and make use of new solutions and new surroundings [9]. Sustainable environmental development requires a balance between economic, ecological, and social interests [10] and from a social and cultural perspective, colour competence is therefore useful in design practice.

2.3 Colour in product design master education in Norway

Although the cultural understanding of colours varies, and although ethnographic studies demonstrate various cultural meanings of one colour, the social anthropologist Taussig criticize that the use of colour in the environment often is based on an indexical use of colour codes [7]. A pilot study in Norway has shown that in some companies that aim for design to achieve strategic competitive advantage, the leaders think that knowledge about colour is one of the least important competences they expect from a designer. This is not only happening in business life, but also in design education. Although there is often an introductory course in colour at the bachelor's level, colour is rarely mentioned as a learning outcome in the master curriculums of Norwegian design education. The institutions with master curriculums in product design, industrial design, furniture design, and engineering product design have colour in the curriculum but the only learning outcome on a master level was, 'The basic course focuses primarily on the design aspects of industrial discipline, through individual design and an aesthetic exploration of two- and three-dimensional expressions, including the use of colour'. Other descriptions were advanced on a scientific level but connected to purely technical perspectives on colour. Based on these educational situations and recent studies, a knowledge gap was identified that required more knowledge about implementing advanced learning outcomes on colour in design education at a master level. The research question was, therefore; how can colour competence contribute to a corporate social responsibility at a master-student's level? The aim was to identify what kind of knowledge was needed in design practice at master's level, and to see how this could be implemented with regard to learning outcomes in a master study of product design.

2.4 Method: Case study of colour competence for corporate social responsibility

A suitable method was case study [11] because the colour phenomena could be explored in a real life context, as experienced by professionals and internship master students. In case study methodology, Yin recommended establishing some theoretical propositions based on earlier research in the field, and on practice. The theoretical propositions in the case study were threefold based on the background: The first was that knowledge about technical premises in materials is needed to design colour surfaces. The second was that ethnographic competence is needed to analyse possible emotional experiences of colour in various cultures. The third proposition was that skills are needed to implement a coherent use of colour as indexical signs in health, environment, and safety contexts. These propositions were explored through a case study approach in three contexts: in the glass industry, in a chapel of rest, and in offshore technology. Thus the case studies were validated through earlier studies, practice in the field of education, and in professional design practice [6]. Further, an embedded case study design allows for theoretical sampling in a cross case analysis [11] and by concept mapping [12].

3 RESULTS: COLOURS IN CONTEXT: GREEN, BLUE AND YELLOW

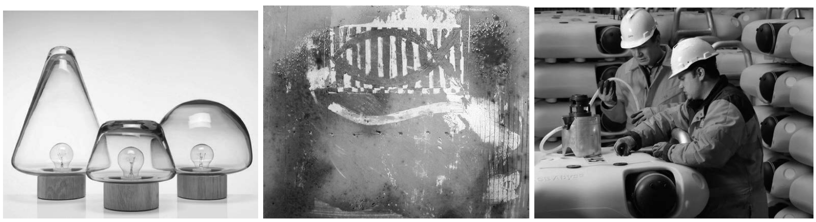

Figure 1 A, B, C. A. Green glass. B. Light blue porcelain. C. Signal yellow interface points

3.1 Case study 1: Transparent tones of green glass for lamps in the glass industry

The first case was a master student's development of various green glass lamps in collaboration with the glass industry. The student Caroline Olsson writes on her homepage: 'The Skog series (Figure 1A) consists of several lights in different sizes, shapes, and colours, which can be used in combination with each other or as stand- alone pieces. They are all made out of mouth-blown crystal with a base of oak made by using a wood turning technique. The design is inspired by the large forests surrounding Magnor Glassverk. Skog is the Norwegian word for forest. Simply place a few of the lights together on the floor or on a table in order to create your own little forest.' The lamps are manufactured by Magnor Glassverk. Materials: Oak and mouth-blown crystal. Dimensions: Bruse 255 mm. Furu 310 mm- Gran 455 mm. Light: E27 lightbowl.

In the interview, she explained that, 'The lamps are a good example because that is the project where I have worked most consciously with colours.' The products should represent 'Forest' in shape and colour. The colour contributed to a story about the products, but it was also connected to cultural heritage and the tradition of the company she collaborated with. Through research, she had found out that people have a good relationship with green glass; it reminds many people of old bottles in green tones that stand together. Therefore, the design leader at Magnor Glass Company felt that green colours helped to represent their values and their history.

Health, safety, and environment were addressed by choosing a bulb without heat, which when touched is lukewarm and not hot. It is the opposite to glowing red, and the function of the colours is that if you take on the cool green colours, the feeling is as expected: lukewarm. Technical challenges were resolved through dialogue with the chief designer at the factory and those who worked in the glass production department. They knew which colours were difficult to keep in the cooling phase when there were different types of tensions in different kinds of glass. There were many tests and a lot of glass was discarded. She tried many colours in the process, to choose a suitable triad. The composition of this colour triad was one of the most complicated tasks; the form and colour of the lamps were not supposed to be too figurative or to give overly clear references to a forest. The associations would possibly first occur when multiple lamps stood together so becoming a 'forest'. There was a slight complementary colour contrast in the foundation through the use of oak colour, which was chosen because it has a texture similar to small branches, where the fibres follow the shape of the trunk of a tree. Through complementary contrasts perceived by the eye, new colours could emerge, and there were additional colours in overlaps created by transparent tones from moss yellow to aqua blue to aqua green.

She explained that during her studies, she had gradually begun to miss more knowledge about colour, and at the end of the master study, students had discussed in class that they should have known more about it: 'We did everything the safe way because it was the last exam. We tried a few colours but it felt risky. The exception in my case was these lamps. Now that I'm working in the design profession, I see in practice that the purpose of colours can be particularly helpful in marketing by use of photography.' This photo (Figure 1A) was shot by the photographer Kaja Bruskeland. Olsson believed that it is important to focus consciously on colour throughout design study. The photos created an increased value in marketing and added value where customers related to the product because the colour reinforced its story. She also believed that the use of colour was inspiring for her own creativity in the design process, because it allowed for a different way of thinking and initiated thoughts about new ranges and collections.

3.2 Case study 2: A light cobalt blue ceramic surface for art in a chapel of rest

The second case was the development of a specific blue ceramic colour surface (Figure 1B) used in public art in a chapel of rest. Through participatory design, colour was implemented in a mourning room integrated in the church. Participatory design had been chosen because it ethically and emotionally could contribute to create a meaningful surrounding. In the study, the mission was to create an atmosphere of spiritual guidance. The implementation of the solution was therefore not limited to technical challenges, but strongly related to people's emotional experiences. Colours were developed based on ceramic crystal structures and their optical properties. Studies of technological behaviour of colours in the Co-Cr-Fe-Mn system were carried out to define the best compositions and to disclose the role of crystal chemistry in colour expressions and pigment-glaze interactions. Categories of colour phenomena that were identified in the study were based on the procedure that was used to connect colour, emotions, and environment. Eventually, material experiments of colour shades were developed and connected to people's experience of hope. Thus it was shown how the technologically developed colour through participatory design could be associated with a cultural phenomenon in a chapel of rest.

3.3 Case study 3: Signal yellow and reflective light in the offshore oil industry

In the third case, signal yellow was used for safety reasons in an offshore context in the oil industry (Figure 1C). In an interview, the designer Nenad Pavel explained that his experiences from the oil industry were not from oil platforms but from a seismic anchor ship where one examined the seabed. He was hired to help to create a subsea seismic sensor for measuring the seabed, a sensor that could be operated via a robotic operative vehicle (ROV). He said that there was, in general, a different use of colours on the water and on board the ship. It was generally a completely new context for him. He said, 'I got a culture shock'. He had to think quite differently than he had done earlier as a designer. 'I attended a safety course at once, and learned to jump from a platform, how to position my arms and to look up, not just around me; one gets a whole new sense of how to be. I let myself fall from a helicopter into the water, and it was similar simulations in a pool. You were a kind of James Bond after that.' As a designer he was used to thinking about user experience, colour, and shape, but now suddenly he thought security - security - security and then: function - function. He also put in many hours in modelling CAD. Now, planning the design mostly revolved around security and legal procedure; the colours were just there to ensure that everyone would know what was being talked about and that everyone knew what an interface point was; under water, there should be a common understanding of the equipment. 'Everything is very pragmatic. All the ships I saw were red outside and white inside; they followed an industry standard.

For the underwater sensor, he first considered various colours in yellow and orange, but when he asked the supplier, they came with a book of rules on the use of colour. There were examples of how to design interfaces, and all interface points; it was all about suppliers and implementation of technology. 'There were components you purchased and put together.' There were strict rules for the use of colour under water, and different rules for colours used on ships. This was because all things under water had to be seen with a camera from a ROV. The camera technology was essential for colour selection. It was common to have yellow colour in all subsea products, because then the light and the reflection of light were easier to see. It was especially the interaction points that had to be visible when the robot looked for interface points as orange and yellow dots based on a standard RAL colour palette.

At one point he relied not on the colour alone, so he chose to use some additional measures. For example, metal was used in some places because it was cheapest, and then some engineers, in practice, had marked these locations with orange tape to define the interaction point. The designer had another suggestion which was to use a reflective tape, whereby the ROV illuminating node points displayed in the dark provided clearer references. There were five white dots and a metal piece around omega-shaped hollows that were marked with reflective tapes so that the ROV could manoeuvre with propellers and camera to see into the cavity from a good angle.

'Using the reflective tape was a typical idea I had because of my design background, I think. I experienced that the engineers I worked with thought in a slightly different way because they did not simulate as much in advance; they tried it out in practice, and when something failed, they tried again. They appreciated completed drawings to be a total picture before testing. This was valuable to them because when I made drawings the totality emerged.' He thought that in this way he could use his design skills in geometry and drawing to complement these features. The design product received a national design award for the year's best design in Norway. Something the designer thought was comical was that an article was written about the product in a technical magazine, but it was written in a slightly ironic tone: 'It was a nice yellow colour so that the fish could thrive under water'. The designer thought the article could give the impression that 'now product designers are creating pretty things under water', but the purpose was, he said, to make it more visible and functional with reflective tape, and the yellow colour was already determined in the regulations.

He felt that his earlier design expertise - like use of colour in offset print and colour use in classical drawing and painting were not relevant expertise for this type of project. It was mostly about following rules and to be creative within these frames. He thought it would be interesting to study how to prepare students for such a culture shock: 'One thing is to do your research with observation and interview. Another thing is that designers also need to go into completely new roles and contexts; this can be a good thing for designers: to try to be offshore people, to try to be a nurse, to feel it in their bones'. He thought it was important to have the ability and knowledge to understand different practices from the inside.

4 DISCUSSION: COLOUR IN A CULTURAL CONTEXT

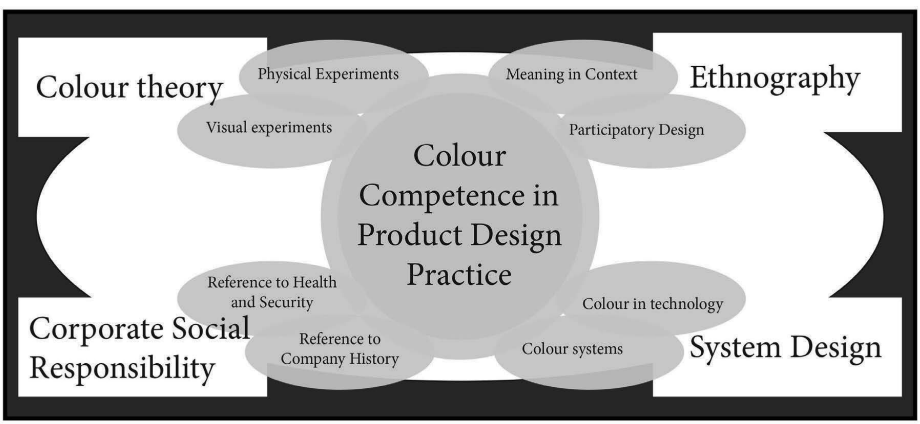

Figure 2. A pedagogical concept connecting colour competence with learning outcome topics and relevant theory

The research question was, 'How can colour competence contribute to corporate social responsibility at a master-students level?' The topics identified through the initial propositions were adjusted according to the findings in the case studies. The case studies tended to focus around colour in context and colour in various cultural settings. The findings are therefore first discussed in relation to colour in a cultural context [7] before some topics are identified through concept mapping [12] visualised as a pedagogical concept (Figure 2) and validation with cross case analysis of the initial propositions as recommended in case study research [11]. Finally, this was connected to how design education at higher levels may have the advantage of implementing the use of colour in the study plans [3] because, through ethnographic methods and participatory design, empirical data can be generated in new ways

[7, 13]. The materiality of colour is, in this case, therefore an integral part of the concept, in line with other non-figurative qualities, such as texture and shape. Taussig [7] reflects on how colour is integrated into a cultural context, and in his search for the 'sacred colour', he exemplifies with blue several times. For instance he does not see any relation between a colour and a specific value; rather, he sees the colour quality as being connected to each unique situation. Further, he sees colour like no other substance we have ever seen or can imagine, but more like a substance which has no substance, suspending the laws of time and space, manifesting itself in different ways as a 'polymorphous magical substance'. An example which he uses is the colour blue emerging in the blue linen used in the mummification rituals in Egypt in 2400 B.C In this context, he describes colour as the divine breath that gives life to all creatures; 'drawing gives shape to all creatures, but colour gives them life'.

4.1 Conclusion

The learning outcomes identified in the study were based on the idea that colour could be more included as a relevant topic at masters level of product design. It seemed like the advanced experimental approaches promoted by Goethe and Albers are still valuable, but that in design practice more theories about contexts are necessary for designers to be able to contribute to corporate social responsibility. Therefore, the first learning outcome identified was that students should have an advanced understanding of how colour can be substantial in certain contexts of design practice. Another learning outcome was that knowledge about technical insight in materials and understanding of the systems in which they were practicing was needed to design colour surfaces. Further ethnographic competence was needed to analyse possible emotional experiences of colour in various cultures and work places that contribute to the values of a company. Finally a general competence on product semantics was needed to implement a coherent use of colour as an indexical sign in health, environment, and safety. The study thus identified a variety of technical and emotional knowledge, skills, and general competence that was needed to understand how colour in product design could be experienced in a broader cultural perspective.

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MANAGE. CREATE. PLAY. PRACTICES FOR TEACHING DESIGN PROJECT MANAGEMENT THROUGH THE CREATION OF BOARD GAMES

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ABSTRACT
In Brazil, it can be seen that courses and lectures in most undergraduate design programs usually focus more on design creation than on project management itself. As a result, undergraduate education and training promote the development of skills and abilities but fail to address project management tools. In an attempt to modify the context described above, a course on design-oriented project management was planned and implemented in an undergraduate design program in a Brazilian university.
The above-mentioned course is taught in the eight semester of the design program, and students are urged to develop a board game delivered in a marketable format that can be played within one hour. In the last eight semesters, 98 undergraduate design students developed 23 board games. The course taught the students how to lead a project while facing constraints and difficulties that resemble those found in the market; thus, they had to combine the creativity of design with the need to manage a design project efficiently. At the end of the course, students submitted a project management plan containing all documents generated, controlled and reviewed for the development of the game.
This paper describes the practices applied for teaching design-oriented project management, in order to make it more attractive to students. We reflect upon our experience with the course and the contents that the students have learned in order to review and update their managerial goals, based on the creation of the board game and the project management plan itself.

Keywords: Project management, board games, collaborative design, learning by doing, assessment and feedback.

1 INTRODUCTION

The year is 2168. The Earth's natural resources are nearly depleted. The four world's biggest economies have developed a joint project to build a large spacecraft to travel to a planet whose characteristics are similar to those of Earth. During the journey, these four economies must cope with various situations that will put the spacecraft at risk. Such situations produce conflicts that must be resolved by the travellers. If the conflicts are not resolved, part of the spacecraft will explode. When the conflicts are resolved, the members of the spacecraft gain resources and popularity marks. If the aircraft arrives on the new planet, the nation with the largest number of resources and highest popularity will be the one that will dominate the next Earth. However, if they do not settle the conflicts caused by dangerous situations that may arise, the entire spacecraft will explode and the human race will be annihilated. In this case, there will be only two outcomes: one nation wins and all travellers survive, or all of them die.
The above context is part of the game MAYDAY 2168, which was developed in the design-oriented project development management course of the university where the authors of this paper currently teach. The game was developed within four months and the design process was entirely planned and controlled using project management concepts, techniques and methods. This way, both by students and the course supervisor can experience learning-by-doing.
The course has been taught since the second academic semester of 2009, and it has been replicated and improved over eight semesters. In this period, 98 undergraduate students of graphic design and product design developed 23 board games. Throughout these semesters, the students learned to lead a project while facing constraints and difficulties that resemble those found in the market; thus, they had to combine the creativity of design with the need to manage a design project efficiently. In this sense,

this paper describes practices for teaching design-oriented project management, in order to make it more attractive to students by presenting contents and activities that resemble those actually found in the market.

2 LEARNING-BY-DOING

Politicians and researchers acting in the field of education claim that the use of unconventional teaching practices is important for students' learning process [1]. These practices have a positive impact on the quality of teaching and have urged the search for the necessary means to implement them in the classroom [1]. One way to achieve this is by developing learning-oriented projects. Such projects are very important because they have the potential to simulate the real world during design education and justify the development of tasks that enable students to deal with problems not previously discussed in the classroom [2].

It is known that design students have an intrinsic desire to develop things, always questioning how such things work and relate [3]. Thus, the search for elements that simulate real life requires the inclusion of other contents (not previously taught) in the course syllabus to provide students with the competencies and skills that will help them manage and develop design projects. Program contents should allow students to experience situations that would make them capable of dealing with strategic actions and change management, as well as to exercise the power of persuasion on their work team [4]. This corroborates our desire to develop a course on project development management focused on action learning, or learning-by-doing.

Taking into account that designers operate more and more collaboratively [5] and work in international environments which require a sound communication channel between suppliers and producers [6], efficient project management is mandatory. In this context, developing collaborative projects in the classroom is important to train students to solve complex design problems through team work[5], making them deal with different experiences and ideas [7]. This can minimize risks of loss or redundancies in the communication channel used by the members of multidisciplinary project teams, and also increase the efficiency of the process of development of a new product or service.

Thus, the course presented in this paper aims to discuss the students' appropriation of the theory by means of the practical application of project management methods and techniques in the development of a tangible product, i.e., a board game that could be developed during an academic term.

In social sciences, games and simulations are largely accepted as important learning elements, because they are considered unconventional teaching tools that complement those used traditionally [8]. Such elements motivate students because they form an action-based learning approach (learning-by-doing) through real life simulations [8]. Playing the game triggers the students' playful side, strengthens the team experience and deepens the sense of belonging of each member of the group [9]. In addition, the use of technologies with simulations and games reinforces the learning process oriented to real life experience, allowing students to interact socially with their peers [10]. Despite the existing awareness of such importance, it can be seen that the use of games as a teaching method has been sufficiently addressed in the literature, but not game design itself [11]. This suggests that game design should be worked on and explored, and it should also be more effectively integrated with the project management process.

Unconventional teaching methods also require that the assessment of each student and also their respective teams to which the student belongs be made in a differentiated, individualized manner. Thus, a key issue to be addressed during project development is how the supervisor will give feedback to students. In this case, the learning-by-doing approach has best results when supported by a regular process of reflection and feedback of students and their supervisors [12]. Thus, it is important to give feedback on the performance of the players, guiding them in their actions to achieve their goals, and this must be done throughout the development of the project [13]. Therefore, it is understood that the supervisors of the design project management course should provide constant feedback on the management process, because in doing so, the students will understand the effects of their decisions in (almost) real time.

3 COURSE STRATEGY AND DEVELOPMENT

The course whose teaching practices will be presented in this paper is called Design-Oriented Project Management. It is a mandatory course taught only in the penultimate year of the graphic design and product design programs, after students have attended prerequisite courses on design methods in the first three years of their undergraduate courses. The course is taught over 18 weeks, with four hours of class per week. At the beginning of the semester, students are divided into groups that represent the teams of the project. Each team is urged to develop a product that must have the following characteristics: it has to be a board game playable in one hour; it cannot be a digital game; and it must be delivered in a marketable format. The project must be managed in accordance with the project management practices discussed in the classroom. In addition to designing the board game, the students also have to develop their project management plan.

Design students are grouped into teams of three to five members. Students' majors were graphic design and product design. As a rule, it was defined that each group should have at least one graphic design student and one product design student in order to foster integration between the two areas.

The development of the course was based on the strategy of dividing the modules into project management contents according to PMBOK areas [14]: integration, scope, time, cost, quality, risk, procurement, communication, and human resources. Each module was taught in three classes; the third class was devoted to practical application of the concepts previously seen in class for the management of the board game project. In the first class following the end of each module, the teams made presentations on how they applied the project management methods of the respective PMBOK area.

Figure 1 shows the framework that was created and improved over eight semesters, which is divided into three major areas, as follows: management, create and play. In the "management area of the framework, concepts of PMBOK are presented. Initially, the contents relative to the need to determine the stakeholders' expectations are defined. In this case, stakeholders are the students and the course supervisor. During this first part of the semester, supervisor and students also define how the team members (students) will be coordinated. Thus, in the first classes of the course, each team chooses a student to be the manager of the project to be developed. The project manager assigns tasks, plans and controls the team's activities and often prepares a progress report to be submitted to the supervisor. The theoretical content about quality is not reviewed in the course, because there is another course taught in the university that covers this subject. The students, however, seek to manage the process quality by performing a design critique as an attempt to deliver a product that will meet the specifications required by the supervisor at the beginning of the semester.

The course was designed to ensure integration of the project management theoretical content with the design methods used by students while designing the game. In this case, because it is a compulsory course at the end of the program, and taking into account that the students have already acquired knowledge on design methods discussed throughout the undergraduate program, each team can choose the methods they will use in order to develop the game.

The first disciplinary modules cover integration and scope (Figure 1). Students should then develop a project charter and the work breakdown structure to describe the scope of the project. Such deliverables must be developed in the "create" area of the framework. In parallel, the groups should begin a survey on board games in order to have insights for the game that will be developed.

Each group then presents the project charter and the scope of the project to the class using multimedia resources. At this time, the supervisor should give feedback on the process of construction of such deliverables. This also offers a learning opportunity to the other groups that attend the presentation. This moment is also important for the supervisor, who can see how students apply his teachings, so he can provide a learning-focused feedback [15]. After the presentation class, the course continues by following the same procedure. Table 1 shows the modules and their respective deliverables.

The students also have access to the board games developed in previous semesters as well as their respective project management plans. Then, in the first classes of the course, the "play" area of the framework begins. In this case, in some specific classes, or extra-class activities, the students play previous games, and analyse and reflect on what to do and not to do, thus gaining experience to develop their own project.

Development of the board game itself begins after the stage of research and insights, and after submission of the proposed Gantt diagram to the supervisor. Still in this presentation, the students should justify their initial insights, so that the game development process may start.

Table 1. Course modules and deliverables

Module	Deliverables
Integration and Scope	Project Charter and WBS
Time	Gantt Diagram

Cost	Cost Quotation
Risk	Risk Analysis
Procurement	Contract
Communication	Communication Plan
Design Process	Board game and manual

There are still two important stages to increase the chances of achieving quality deliverables: development of the game manual and testing the game that has been created. The manual begins to be drafted when the students have a more detailed concept of the game. The students then go on designing and testing the game with prototypes to enable them understand the problems, thus enhancing their critical thinking significantly [16]. The final stages of development of the manual are tied to the completion of the board game itself. Thus, the supervisor requires submission of a draft of the manual for his review three weeks prior to the final test of the product. Accordingly, the supervisor can provide feedback on the manual as well as on the game features so that the students can improve them until final delivery.

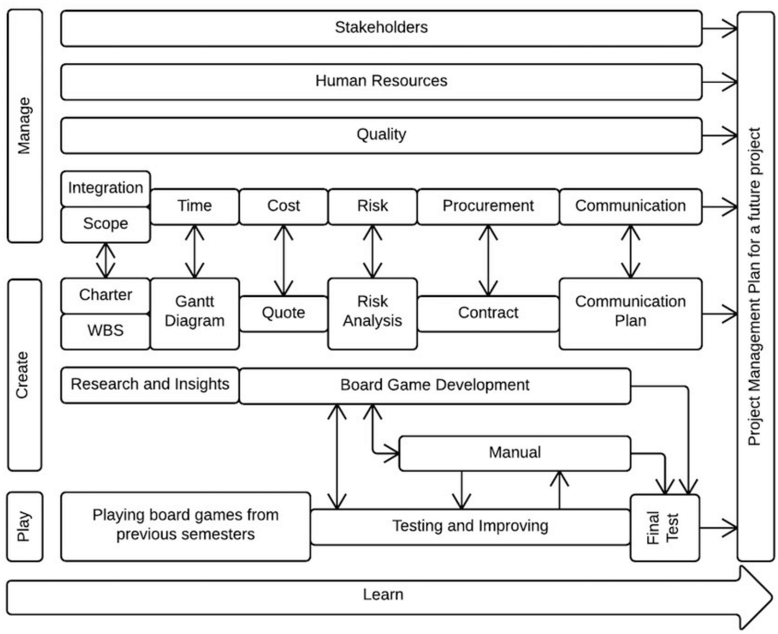

Figure 1. Course framework

A week before the final test, the prototype of each group is assessed by the students of the other groups. As a result, an informal evaluation takes place when the students play the games of the other groups. A member of the group that developed the game is required to stay next to the players, only watching but not allowed to interfere. Such observation allows the member of the group to take notes of the feedback for the final test of the prototype and to make minor modifications before the final product testing.

On the day of the final test, students are supposed to have submitted a project management plan containing all documents generated, controlled and reviewed for the development of the game. In addition, the game they developed is played by undergraduate and graduate students for evaluation purposes (Figure 2).

Figure 2. Example of games and playtests

Playing the game serves as market feedback from future consumers. Thus, as occurred in the prototype test, in the week prior to the final testing, the games of a group are assessed by students of the other groups. Students should assess the game in various aspects: ease of understanding the manual, packaging, graphic parts, and the game concept. The marks given by the students are anonymous and correspond to 5% of the overall mark that each student will receive at the end of the semester. The respective project manager also evaluates each student at the end of the course, and this mark corresponds to the performance of the team member in project development. On the other hand, the course supervisor evaluates the performance of the project manager. The final mark of each student ranges from zero to ten and is made up of the evaluation of five specific areas, as follows: project management and control plan (40%), board game (40%), student engagement (10%), performance of the team member in project development (5%), and assessment of the game by students of other groups (5%). The project management plan and the board game account for 40% of the overall mark each. The objective of this procedure is to make students aware of the importance of balancing efforts so that both the board game and the project management plan are delivered while fulfilling the scope, deadline, cost and quality requirements expected at the beginning of the course. In this case, the performance of team members is assessed on an individual basis. Each project manager evaluates the member of his or her team, and the course supervisor evaluates the project manager of each team according to the project management theory presented in class. The course supervisor checks if the contents from PMBOK [14] dealt with in class were properly learned during the course. For this purpose, the course supervisor assesses the documents submitted as well as the performance of individual students or the whole team.

In the last class of the course, which takes place after the game playtest day, the teams submit their proposal for the project management portfolio of another game to be developed in the future. They use what they have learned in the course to review and update their managerial goals, based on the creation of the board game itself.

4 FINAL CONSIDERATIONS

The framework of the project development management course enabled the teaching process to be carried out with more fun and associated with the development of two tangible products: the board game and the project management plan. Students lacking previous experience on project management contents usually consider project management practices as a difficult course to apply in the real world. In some cases, their previous experience was based on the management process practiced by the design offices where they worked as interns. Most designers who run these offices have not attended a project management course at university. As a result, their empirical knowledge has developed organically on a trial-and-error basis, thus leading to the establishment of an informal project management culture. The practices presented in this paper are an attempt to change this situation.

After the final test day, some comments made by students suggest that the course could help them in the future with actions that influence such culture. "Before this course, the quotations that I used to prepare for a freelance job were usually estimated based on what my colleagues said. I did not know exactly how many hours should be allocated to complete the project, and sometimes I ended up working more than I had anticipated", said a student in the last class in the second half of 2014, showing his appropriation of the concepts that were taught on project management.

The development of the course has opened a possibility for students to work using both theory and practice. In addition, it has created a significant portfolio of board games. Out of a total of 23 games created until now, one is registered under a patent application, two won a major Award on Design in southern Brazil, and two others got honourable mentions in other editions of the aforementioned prize. This has motivated students to develop, every new semester, quality board games that, to a greater extent, require planning and continuous control of their project management processes. Games are also paving the way for the conduction of experiments in the field of project management and design. The Mayday game, which was briefly described in the introduction of this paper, has been reformulated by one of the students who developed it, in order to enable us to examine how inexperienced (novice) and experienced students resolve conflicts. The aim, therefore, is to identify elements that can enable us to be knowledgeable about how to create a design team capable of dealing with different kinds of individual goals of each member of a project team.

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Chapter 16

Learning Paradigm

A PRELIMINARY COMPARISON OF DESK AND PANEL CRIT SETTINGS IN THE DESIGN STUDIO

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ABSTRACT
'Desk Crit' has been described as the most important critique setting for teaching design. This approach has been shown to be beneficial in providing different perspectives on design problems to students and bridging to professional practice. However, some issues may be envisaged in this style. In this paper, we try to address these issues by adopting a panel based critique setting named 'Panel Crit' in a second year product design studio. The 'Panel Crit' setting is then compared with the 'Desk Crit' setting through a questionnaire and a structured interview with 16 students. The survey protocol is based on an evaluation of teaching survey and consists of 12 close-ended and three open-ended questions. The protocol compares the critique styles across four dimensions: communication, learning, feedback and satisfaction. The preliminary results reveal the effectiveness of a panel-based critique in providing unambiguous feedback, avoiding multiple presentations and increasing time efficiency during studio sessions. However, our results confirm previous research findings which highlight the importance of 'Desk Crit' in conveying fundamental design skills, introducing students to design practice and showing practitioner's approaches to design problems. We believe our findings could contribute to the understanding of how critique settings impact student's learning experience in design studio.

Keywords: Design education, design studio, design critiquing, critique setting, studio-based learning.

1 INTRODUCTION

Since the end of the 19th century, critique has been recognised as a central element of design, architecture and art pedagogy [1-4]. Among the different types of critique setting [2, 3, 5-9], desk crit has been considered for being the most effective [10-12]. It's benefits have ben emphasized in its capacity to supervise each student's progress over time [8, 10], in enabling design instructors to lead individual students to see their design problems from a professional viewpoint [3] and in conveying an extensive range of fundamental design knowledge [11]. However, in a design studio module of a second year product design and manufacture programme, we envisaged some issues regarding this setting. For instance, it was noticed that desk crit setting led to advices/comments being often repeated and some advices/comments were contradictory, resulting in students' confusion. Moreover, not all learning outcomes were met, as tutors focused on some aspects of the project only. The one to one tutoring was identified as the main problem. In addition, with desk critique students have to present the same project progression every time to each educator. This may dissuade some students to present all the aspects of their project to all the educators, so that some educators get a different perception of the project. Finally, in 'Desk Crit' students may over-rely on educators' coaching, which may impede the development of their independent thinking and problem solving attitude. In order to tackle these issues, we develop a new critique setting that we called 'Panel crit'. In this setting students present informally to a panel of instructors their project progress and each instructor gives a feedback in a three-to-one discussion. This article presents the 'Panel crit' setting and a preliminary comparison with the desk critique from a student perspective. In order to perform the comparative study between the settings a case study methodology has been adopted with a quantitative and qualitative approach. This paper is organized as follows, section 2 presents a literature review on desk crit in Studio-based learning, section 3 the description of the critique settings tested in project, section 4 the methodology adopted, section 5 a description of the results and section 6 the discussion and conclusions.

2 DESK CRIT IN STUDIO-BASED LEARNING

Desk critique also called crit or preliminary crit has been defined as a form of intermediate formative assessment that takes place in the studio-based learning environment [5, 9, 12]. This critique setting takes place as an active one-on-one informal discussion between design student and one or more tutors, in which each tutor separately gives a formative feedback on student's problem solving process and work [2]. This form of critique is held daily or twice weekly during the design studio sessions for a an average time of 20 to 30 min per student [2, 13], typically at the student's desk [2, 5] and often takes place during the entire period (typically a semester of 12 or 16 weeks) of a studio module [8]. During the critique, the tutor reviews the student's progress by looking at the student's preliminary material, which could be found in form of research reports, sketches, sketch models, CAD models, renderings, prototypes and visual presentations [2, 13]. Often the form of the material is required by the tutor, based on the different stages of the design process, or left up to the students, if they have achieved an adequate level of expertise [2]. Looking at the student's work, the tutor identifies the issues of the student's project then proposes particular improvements to the design, that he or she feels will be better solve a particular aspect of the problem [2, 9, 13]. Concurrently, the tutor shows to the students a practiced process of inquiry, different viewpoints and solutions of the problem [11] and how to reflect on his/ her own process of designing [2]. Finally, the tutor initiates the student to a specific language about designing. In doing so, he/she acts as a master demonstrating the appropriate behaviour, values, design strategies, and thought processes that professional designers use [14]. After the critique, the student has to critically assimilate the comments from the tutors and further explore and revise his/her design. In the following studio sessions, the tutor will then review the student's work and suggest further improvements until the end of the project [9, 13]. Several contributions to design pedagogy have been correlated to desk critique. Desk critique does not only provide a tool to highlight problems in students' designs but it is also considered the primary site for bridging students into professional practice [1, 5], introducing design professional language [2, 9], improving students' capacity to communicate design ideas and process [1], providing different solutions or perspectives to problems [3, 9, 11] and pushing students to think and be critical about their own work [13]. However, also different limitations has been highlighted with desk crit. Dutton underlined how in desk crits the overpowering authority of the instructor discourages students from participating freely in debate, asking questions, and reflecting on their own designs [8]. Other studies revealed how students may feel they are expected to work round-the-clock to prepare for the critiques, with little time devoted to sleep or healthy eating [15]. Additional studies reported that during critique sessions, students described feelings of embarrassment, humiliation, frustration and not being heard during their presentations (Anthony 1987) [9]. Furthermore, Utaberta emphasised how these feelings could have a further detrimental effect by orienting students to just look for tutors' acceptance and if this doesn't happen, by feeling disappointed, losing other statements and suggestions coming after and focusing only on the exact solution. Beside this, also tutors may experience frustration and believe that students don't grasp what they told and act different from what expected [9]. Kosara also highlighted the importance of tutors experience in avoiding arguments based on taste and preferences instead of objective principles and the risk that critique could limit the exploration of new and unusual ideas when adopted too early in the creative process. [4] Some design educators have also decided to remove public critique settings from their design studio [15]. Utaberta created a list of weak points of critique. According to the study, critique seems to limit collaboration and participation between students, to lower tutors' feedback because it could interfere to students' creative process, to provide ungrounded feedback without giving suggestions about what students can do, to put pressure on tutors due to high tutor-student ration, to focus on the "end product" instead than on the process, to compare students with each other and to have a strong emotional impact [13] which intensify students' stress and anxiety and consequently impacts on student learning.

3 PROJECT SETTING

The project has been carried out during a second year design project module in a bachelor degree in product design and manufacture. The module was convened during autumn 2014 by two full time academic staffs and two part-time design consultants, tutoring sixteen students for four hours twice a week. The module lasted for twelve weeks, in which three different briefs were given to the students. Students had four weeks to complete each of the briefs and present the final design. A desk critique setting was applied during the first brief, while a panel crit setting was applied during the second and the third briefs.

3.1 Desk crit setting

The first project was based on a desk critique setting. During this project, students were requested to develop a child outdoor toy. The tutoring sessions were on a one to one (one tutor-one student) basis and the students were free to select their design method. Thus students were allowed to manage their own schedule. Figure 1 shows the layout of the setting, in which students were sitting in their desk and tutors walked around to give individual feedback.

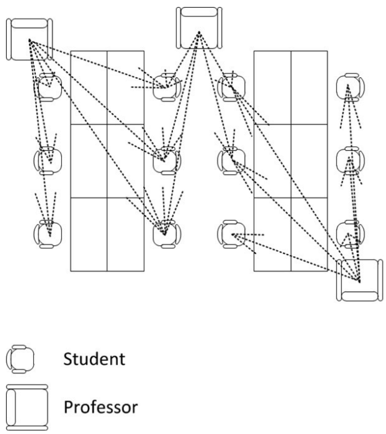

Figure 1. Plan of the desk critique setting

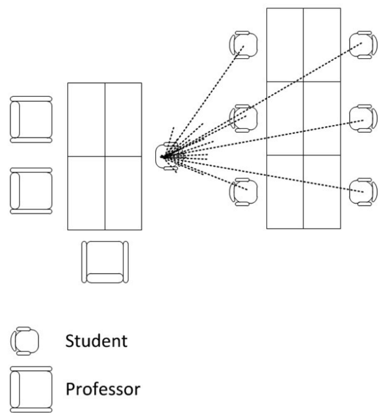

Figure 2. Plan of the panel critique setting

3.2 Panel crit setting

During the second and the third brief, a panel critique setting was adopted during the studio sessions. The products the students had to design during these two projects were a set of sport accessories (googles, water bottle and watch) and a parabolic electric heater. 'Panel Crit' refers to a critique style where a panel of faculty and non-faculty members (usually local professional designers) reviews informally an individual student over his/her progress each design studio session. Figure 2 shows the plan of the panel crit setting. In this setting, usually three tutors sit around a table and each student at the time comes to present his/her progression. Each of the tutors gives his/her feedback. To improve students' project management, students were given a design methodology and specific tasks to be completed during each session. The design method was built in different stages covering research, data analysis, concept generation, development of technical aspects and communication (Figure 3).

Problem	Data Collection	Data Analysis	Concept Generation	Creativity	Development	Communication
Interpretation of the brief • Requirements • Possibilities	Product autopsy • Product components Try it yourself • Product testing Target definition • Country • Culture • Subculture	Target user • User persona • Income average • Age group • Daily life Future forecasting • What people are doing • What is the current trend	Design attribute • 3-5 attributes Creative techniques • Brainmap • Brainstorm • 2 extra (compulsory) Moodboard • Target user • Concept • Reference for creation • Environment of use	Idea generation • Sketches • Sketch-models • Thumbnail sketches	Final design • Sketches • Exploded view • Selection of materials • Selection of manufacturing processes • Engineering drawings • Ergonomics	Presentation material • Digital illustration • Moodboard • Other boards

FINAL PRESENTATION

Figure 3. Design methodology adopted in brief 2 and 3

For each step, the students' performance was evaluated as task completed, incomplete or failed to present. The evaluation of the students' performance was made by all tutors to ensure consistency and each step was assessed to ensure that problems were spotted early on and that students performed all the steps.

4 METHODOLOGY

A case study approach [16, 17] using mixed methods [18-20] was implemented to inform the study. The quantitative data was collected using a 12 items Likert scale questionnaire based on a form for student evaluation of teaching already employed at the institution. The 12 items of the scale covered the topics of communication, effectiveness in learning, feedback and learning experience. Instead, the qualitative data was gathered through a structured interview protocol based on three open-ended questions. Three of the four authors of the paper, were design instructors in the module and they participated as faculty staff to all the critiques. The other author has 6 years' experience of Studio-based learning and he was responsible for surveying and interviewing the participants, but he was not involved in the critiques and he hadn't taught to the students before. This ensured that the students were not afraid to express their opinion about the settings during the structured interview.

5 RESULTS

Over 17 students that participated to the design studio, 12 questionnaires and interview were collected and included in the study. The results were analysed and processed to compare the difference under two conditions (i.e. desk crit approach and panel crit approach). Both quantitative data (users‟ ratings) and qualitative data (users‟ comments) were gathered during the study. For quantitative analysis, data was aggregated over the four factors (i.e. communication, effectiveness in learning, feedback and learning experience), and differentiated according to the main within subjects factor. This showed how these factors varied according to difference design teaching approaches. Wilcoxon Sign test in Siegel and Castellan [21] for non-parametric data were calculated for the main within-subjects factors. Quantitatively, a Wilcoxon Sign test for two dependent samples showed students' rating in Panel crit approach is significantly higher than that in a desk crit approach ($N= 16$, $z=-2.202$, $p < .05$). The Wilcoxon Sign test further showed a significant different in the aspect of 'communication', according to whether they were using panel crit approach or a desk crit approach ($N= 16$, $z = -2.224$, $p < .05$). No significant differences was found in statistics in the aspects of 'effectiveness in learning' ($N= 16$, $z=-1.56$, $p > .05$), 'feedback' ($N= 16$, $z=-1.533$, $p > .05$) and 'learning experience' ($N= 16$, $z=-1.225$, $p > .05$). Summary diagram is shown in Figure 4 to present the mean assessment for condition, based on whether the participant was undertaking the desk crit, or panel crit. The ratings shown for each condition are a mean, equally weighted score across the four dimensions (i.e. communication, effectiveness in learning, feedback and learning experience. The ratings shown are aggregated scores on 'strongly like' (5) to 'strongly dislike' (1) scales. The error bars represent +/- 1 SD of the mean in all cases.

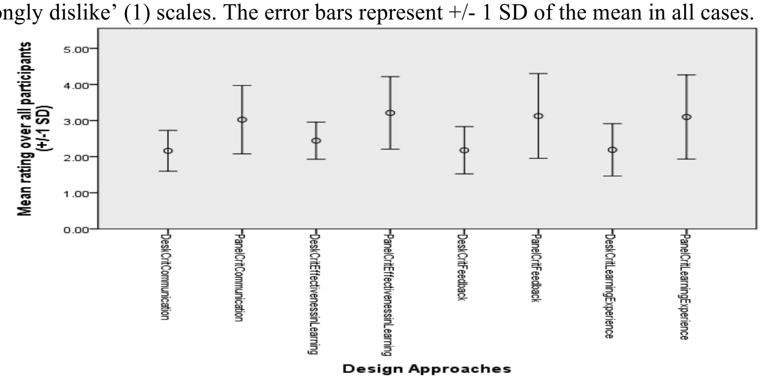

Figure 4. Comparison between crit settings

The qualitative data (interviews data) were analysed using an Emergent Themes Analysis approach [22] to categorise the verbal data from the case. The answers of the open-ended questions were transcribed on a computer-assisted qualitative data analysis (CAQDAS) software and analysed. The analysis found 26 themes, however, theme highlighted by only one student were excluded from the study resulting in 14 themes.

Table 1 shows the summary of the positive and negative aspects.

Table 1. Positive and negative aspects of desk and panel critique from open-ended questions

	Positive	n'	Negative	n'
Desk crit	More detailed feedback	4	Not enough time to discuss with each tutors	4
	Different perspectives	4	Not time efficient – there no time for work	2
	More communication	4		
	Tutors are freer to express their opinion	2		
	Caring	2		
Panel crit	Time efficiency	7	Lack of detailed feedback	10
	Feel more motivated to work	3	Focus on evaluation rather than formative feedback	9
	Clear direction	2	No time to contact the tutors after the crit	2

The more prominent positive aspects of desk crit that were experienced by the students, were the possibility to have a more detailed feedback on their work, the different perspectives on their project given by the different tutors and generally a capacity to have more communication with the tutors. From the point of view of the negative aspects, the students highlighted that desk critique doesn't give them enough time to discuss with each tutor and that the time is not managed efficiently during this setting. For instance, the time between a meeting with one tutor and another is considered wasted because not enough to work on the project. Panel critique received generally more feedbacks from the students. From the side of the positive aspects, the students strongly highlighted that this setting was more time efficient than the previous because there were less interruptions to their work. They also felt more motivated to work due to pressure caused by the panel. Then two students highlighted that there was a clearer direction compared to desk crit. On the other side, three main negative aspects of panel critique emerged from the students' answers. The first main negative aspect was that the feedback of the panel critique was considered by the students not detailed enough as compared to the feedback received from the desk critique setting. The second negative aspect was related to the focus of the feedback that was perceived by the students more as evaluative rather than formative. Finally, two students stressed that in the panel critique setting there is only one time to contact the tutors during a studio session and consequently there was no possibility to have a second critique during the session were to ask more explanations and check if they had understood correctly the.

6 DISCUSSION AND CONCLUSION

The results of this study are not intended to be generalizable across different institutional settings and disciplines due to the limited number of students' sample and the analysis of only one factor of design critiquing (the critique setting) [8]. Furthermore, our work primarily focused on capturing the students' perspectives rather than teacher–student interactions. Nevertheless, we believe we have gained a deeper understanding of the design critique setting through our analyses. Our study underlines the value of desk critique setting as a valuable pedagogical tool for studio-based learning. The individual interaction between students and instructors [2], the opportunity to listen to different perspectives on the design project [3, 9, 11] and the capacity to give detailed in-depth feedback [8, 10], are some of the desk crit aspects that our study corroborates to be appreciated by design students. However, we also found one main drawback of this setting which is time efficiency. Although, our class size was only of 16 students, this issue was emphasized in the open-ended answers. Compared to desk critique, our study shows that panel crit has been generally perceived as less beneficial by the students. Quantitative data shows that in each of the four factors (i.e. communication, effectiveness in learning, feedback and learning experience) panel crit achieves always a higher mean and a broader standard deviation if compared to desk crit. Qualitative data supports these results by highlighting how panel crit didn't provide feedback at the same level of depth as desk crit. Students also stressed that the kind of feedback they received in panel crits was more evaluative than formative, which they perceived less useful for their development. However, some positive aspects were also emphasised, such as the more efficient management of time and the improvement of motivation. From our perspective as design tutors, we considered these aspects quite important especially if considered in light of the initial issues that we wanted to address at the beginning of the study. In relation to those issues, we found that contrasting feedback can be perceived by some students as confusing, but by other as a pedagogical opportunity. We consider this in line with Carmel-Gifilen and Portillo study, where even beginner design students were able to appreciate the contribution of different viewpoints

[12]. The study has also shown how a panel critique setting could improve time efficiency one of the main drawbacks of desk crit. Finally, the methodology applied in our study was not capable to investigate the issue of students over-relying on educators' coaching. From our survey, students seem to appreciate tutors coaching; however, we found difficult to confirm if this is beneficial or detrimental to their development as professional designer and in which stage of their educational path this should be emphasized or minimised. Further studies, should investigate this issue by considering different critique factors in addition to the setting.

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INTENSIVES AND EXPERTS: THE DEER PARK STUDIO EXPERIENCE

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ABSTRACT
In July, 2014, The Deer Park Studio was offered as a 12 week course to Australian Industrial Design undergraduate students. The studio was developed as a companion studio to the The Himalayan Ecology Project, a Masters level Industrial Design course, run in India in early 2013. During the transnational studio, teaching staff from Australia and India worked with Australian students in Australia to develop designs for the residents of Bir, in the northern state of Himachal Pradesh, India. The Deer Park Studio was developed using 'design for development' and Social Design approaches and used the report on the delivery and outcomes of the The Himalayan Ecology Project as the primary document. The design of the studio also included an 'intensive phase' during which the academics who taught the The Himalayan Ecology Project took part in The Deer Park Studio. For 10 days they attended classes and in collaboration with local staff consulted with the Australian students, providing contextually rich feedback during the ideation and concept development phase of the studio. This collaborative teaching phase enabled students to design from within a local context but to develop designs that would be relevant and useful in Bir. The students were able to mitigate the limitations of designing for a physically remote and culturally different context and to produce outcomes that drew on their own design experience as well as the cultural knowledge of the visiting academics. This paper discusses the design, delivery and outcomes, both student and academic, of The Deer Park Studio.

Keywords: Social design, design for development, industrial design, design education, transnational design.

1 INTRODUCTION

In Australian Industrial Design degree programs a 'studio' is a course in which students focus on the development of design skills in response to a brief set on a topic chosen by the program or course tutor. The term 'transnational' refers to operating across national boundaries.

In 2014 Deer Park Studio, a 'design for development' and Social Design transnational studio, was offered to 2nd and 3rd year Australian Industrial Design undergraduate students in the Design for Industry stream, a stream that offers courses in which students work with an Industry Partner. For this course the Industry Partner was The Deer Park Institute, an organisation working to improve the well-being of the residents of Bir in the northern Indian state of Himachal Pradesh. The studio was delivered as a companion studio to the The Himalayan Ecology Project studio run in India in 2013. In that course, Masters level Industrial Design students offered their design responses to research they had personally conducted in Bir in collaboration with The Deer Park Institute.

The starting point and benchmark text chosen for the explanation of Social Design as a method was "Design Revolution: 100 Products That Empower People" [1] in which Allan Chochinov discusses "design for social good" [2, p.6] in relation to Industrial Design and Emily Pilloton discusses the her view of design as "problem solving with grace and foresight" [3, p.10] before presenting 100 products that encapsulate the approach of Social Design. However the broader aims of the Social Design, of design that can contribute to 'human welfare' by asking questions such as "What role can a designer play in a collaborative process of social intervention? How can agencies that fund social welfare projects and research gain a stronger perception of design as a socially responsible activity? What kinds of products meet the needs of vulnerable populations?"[4, p.28] were also embedded into the studio teaching approach.

The Deer Park Studio design brief tasked the studio participants with developing products and services that would increase the 'well-being' of people in Bir and it's surrounding regions. The aims of the studio were aligned philosophically with the aims of The United Nations Development Programme (UNDP) for developing countries "which considered issues of culture, social equality, health, nutrition, and education among others" [5, p.111] common concerns of designers who work within the 'design for development' field.
Discussion between the respective partners meant the studio format was modified to include a text from the Indian course that enabled the Australian students to develop their understanding of the issues and opportunities of designing for the people in Bir without ever leaving Australia. This text, a rich and detailed account of the research and the design outcomes of the The Himalayan Ecology Project course, was included as must-read contextual background document for The Deer Park Studio. The change in format also included the addition of an Intensive phase during which the Indian academics visited Australia to act as expert advisors and consultants for the students in Australia guiding the Australian students in developing contextually relevant and useful design for the residents of Bir.
During the Intensive phase the Australian students were asked how they could bring their experience of designing, and their knowledge of designing, for an Australian context into their designs for the residents of Bir. To do this they were guided by the local tutor and the academics from India who had developed and delivered The Himalayan Ecology Project. This approach enabled the Australian students to embed their design knowledge and experience of designing for an Australian context into their design projects for the remote location. This approach also enabled new methods of engagement with 'design[ing] for development' to be explored and the design outcome results retained elements of design from Australian as well as first hand Indian knowledge of location, society and culture.

2 BACKGROUND TO THE DEER PARK STUDIO

The events that led up to the The Deer Park Studio began ten years ago when, in 2005, the Program Manager for Industrial Design at the Australian university initiated an exchange program with the National Institute of Design (NID) in India. The Australian tutor teaching in The Deer Park Studio was the first student from the program to spend a semester at NID. His courses in India involved working with the National Innovation Foundation with grass roots inventors in Ahmedabad. By the time he finished his exchange he had a strong understanding about grass roots innovation as well as design projects that served the needs of the poor and the way designers spoke about such projects.
In 2013 the same academic set up a sustainable transport design project, a week long event that exposed the attendees to the innovation context in Australia and one of the Indian academics was invited to participate. This was followed up with an invitation to collaborate in a 'design for development' studio in Australia along with the co-academic from The Himalayan Ecology Project.
The Deer Park Studio was arranged so that the local tutor would teach the course through the semester and the visiting academics would participate as experts during the course's Intensive phase.

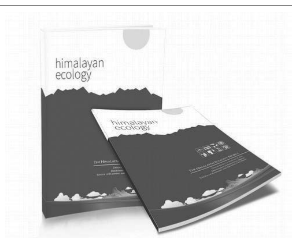

Figure 1. The Himalayan Ecology Project report

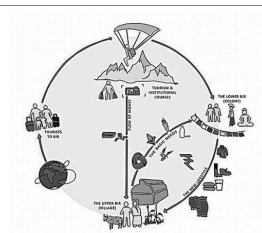

Figure 2. Detail of Indian student work

Figure 3. Indian student outcome

2.1 Himalayan Ecology project

In February 2013, in collaboration with The Deer Park Institute, the Indian academics and students travelled to Bir with the intention of designing for the residents. The studio outputs were 16 design projects developed from opportunities discovered in Bir and The Himalayan Ecology Project report, which detailed the studio process and outcomes. This report was used as the basis of research for The Deer Park Studio and as such provided invaluable research and inspiration for the Australian students. See Figure 1 for an image of the report and Figure 2 and Figure 3 for examples of student work from the report.

3 THE APPROACH TO DESIGNING THE DEER PARK STUDIO

3.1 The design narratives used in The Deer Park Studio: Social design, 'design for development' and increasing the 'well-being' of the people in Bir

As discussed earlier the Deer Park studio was developed as a 'design for development' studio and used the approach of Social Design to enable the Australian students to frame their work. In the studio brief this was presented as designing to increase the 'well-being' of the residents of Bir. This necessarily imprecise direction was used so that the students could have a wide range of design responses to the research that they undertook.

3.2 An approach to designing a transnational studio

The transnational studio approach provided a way for international collaboration between the universities to occur and as a way of introducing students to experts in the particular context of the studio; the inclusion of these experts, the visiting academics from India, provided the means to increase the contextual and 'real world' rigour of the Australian student's projects. The nature of the transnational studio meant that the Indian academics could not be present for the entire semester so the studio was designed around an the Intensive phase. This phase was designed to allow significant time for students and visiting academics to consult and collaborate. In all, the studio had three distinct phases, the Research phase, the Intensive phase and the Design Development and Delivery phase. These are briefly described below

3.2.1 The Research phase

The Research phase was developed using the Himalayan Ecology Project report as the initial research document. This document provided a rich base for the Australian students to work from and allowed the studio to be clearly framed and bounded for students who would not visit the location they were designing for. The research that students undertook in this phase was designed to extend the research in the report, including topics that complemented the original research but that were not covered, or if covered, were explored using different methods such as the analysis of statistics in contrast to the location-based observational research that the Himalayan Ecology students had undertaken.

After conducting their research, the Australian students investigated their findings using techniques such as the Actor Network Theory and presented their results as two posters. The first an infographic that summed up their research, the second, outlined the 'Patterns, Problems, Gaps and Opportunities' that they had identified through their research and could then use to develop design concepts.

At the end of Week 4 of the semester, the Research phase ended with the students, in their research groups, presenting their posters to the visiting academics. This event marked the introduction of all parties and the start of the Intensive phase.

3.2.2 The Intensive phase

The Intensive phase of the studio was a period of 10 days in which the Indian academics visited Australia to provide the students with expert guidance on the social, cultural and contextual appropriateness and usefulness of their ideas and concepts. The Intensive phase is discussed in more detail in Section 5.

3.2.3 The Design Development and Delivery phase

After the Intensive phase, the students worked on the delivery of their projects by refining their chosen design, by the development of models and then the creation of documentation for their final presentation and the end-of-year exhibition. The final outcomes were a model, an exhibition poster, a video that detailed the use of, or development of, their design as well as their project folio. The students delivered these outcomes to an assessment panel and exhibited their posters and models at the exhibition. The local tutor guided their outcomes for the final 9 weeks of the semester.

3.2.4 The Deer Park Project book as a way of capturing and complementing The Himalayan Ecology Project report

The Himalayan Ecology Project report proved invaluable in the structuring and setting up of The Deer Park Studio and also provided an approach that could be used in the development of academic outputs from the studio. The academic outputs culminated in the development of a book, The Deer Park Project, that reflected on and discussed The Deer Park Studio as a transnational and collaborative teaching event. The book was a collaborative effect between the academics involved in The Deer Park Studio and the students that undertook the studio. The Deer Park Project, as a book, draws together the outcomes and outputs of the The Deer Park studio and frames them within an academic context. This includes the relationship between the two studios and presents The Deer Park Studio as a particular way of teaching 'design for development' courses using a transnational approach.

4 THE INTRODUCTION OF TWO AGENDAS

As the The Deer Park Studio progressed, two agendas emerged that were used to further develop the brief and give the students the possibility of developing designs that would be different in type and form from previous projects in the 'design for development' field. They are discussed below.

4.1 How can a group of Australian Students add value to what is already being done in India?

This question was posed to the students in a presentation that considered how design was conducted in Australia, and therefore, how students in Australia, were taught to be designers for an Australian context. The students were then asked to design in an 'Australian' way for the Indian context. Example design cues for this were diverse design projects such as playgrounds, preserving cultural memory through storytelling, tool libraries, farmers markets, public urban lighting, open source design and urban farming. This allowed students the opportunity to design as they would design for their previous studios, drawing on their own skills and experiences as a design student in Australia. The expert consultation from the visiting academics allowed for a free design approach to develop products and services that would still be relevant in the Indian context.

4.2 Design for NREGA

The other agenda was the consideration of the National Regional Employment Guarantee Act (NREGA) as a way of proposing projects that could be developed and delivered with the support of the Indian Government. The NREGA guarantees Indian rural workers one hundred paid days of work per year. The projects that have been traditionally undertaken are orientated towards infrastructure development such as roads. However during the Intensive phase the NREGA was considered as a way for a potential design or project to provide alternatives to the traditional infrastructure projects undertaken through the NREGA; especially if they met the studio directive of increasing the 'well-being' of the residents of Bir. In the end, several student projects were developed that could be considered candidates for the NREGA. These projects included consideration of the production of the designs as a local industry or locally driven activity that could be organised and undertaken by local businesses or community organisations. A few of these projects are discussed in Section 8.

5 THE INTENSIVE PHASE

As the Intensive phase was pivotal in the success of the studio it is useful to discuss it further. The Intensive phase lasted for 10 days during which the local and visiting academics and students worked in a specially chosen location. During this time, the students completed half of their semester contact hours for this course. The location in which the studio was held was separate physically from the usual classrooms and was designated for the exclusive use of the participants of the studio. During this time students were encouraged to make the space their own and the academics endeavoured to create a 'hot-house' atmosphere in which the aims of the studio would be the focus.

This approach was very successful, allowing the visiting academics to be the experts on India and the local academic to work as studio facilitator. The students were able to work uninterrupted, to receive valuable feedback immediately and to incorporate this feedback into their work as it was received. The face-to-face contact with experts who could guide their projects with the knowledge of Bir and India produced an environment where the students developed strongly contextual and useful designs that still retained Australian aspects, concerns and design elements.

6 THE TRAVELLING ACADEMICS EXPERIENCE

As opposed to the Himalayan Ecology Project, where the group of Indian students were not completely unfamiliar with the region, the cohort of Australian students came with a completely different world view and diverse cultural understandings. This unfamiliarity and complete novelty was by far the most valuable resource they brought to the project. Their only connection to Bir was the Himalayan Ecology Project report, and it left them free to imagine, draw from their life experiences and develop entirely fresh perspectives. This new ingredient became the catalyst to redefine the boundaries of the design project and open imaginative new possibilities. Possibilities that were open ended and would trigger further prospects.

This remote situation, another world that Bir existed in, encouraged cutting another cord. Their studio responses felt no need to be bound to 'problem solving' in design, there was much bigger opportunity in creating design with their Australian experience as a tool. Design, as opposed to the case of The Himalayan Ecology Project, did not feel the burden of being born out of necessity. Approaches to design spontaneously steered toward creating products and systems that reinvigorated, enriched quality of life, created new avenues for the community and strengthened bonds.

The Studio also built on the expertise of the Australian students to be able to develop products, services and systems that integrate the use of hi-technology, open-source knowledge systems, technologies that 'leap frog' to minimise environmental impact and contribute to sustainable growth in the region.

7 AUSTRALIAN ACADEMIC EXPERIENCE

Collaborating with the travelling academics was a great experience and as a group it was possible to explore new ways to deliver a 'design for development' studio that overcame problems that arise from distance; both geographically and culturally. The intersection between the knowledge and experience of the travelling academics, the 'hot-house' environment of the Intensive phase, the willingness of the students to engage with the novel experience of such a studio and the ability to facilitate all of these elements within a defined time and space meant that the studio was very successful in terms of richness of the student outcomes. All the students engaged with the specific social, cultural and geographic contexts that were embedded within the studio and were able, with assistance, to develop designs that had both Australian and Indian characteristics.

8 STUDENT EXPERIENCE AND STUDENT WORKS

All the student's outcomes engaged with broader social, cultural and geographic concerns and their design outcomes were much richer for that. Many designs considered the production of the design within the constraints of the capabilities and resources available in Bir and all engaged with the inclusion of the Bir community in terms of community building, employment opportunities or product development and distribution. The outcomes also reflect elements and concerns that are Australian in nature and that are currently being discussed and explored within the Australia context. These elements and concerns were able to be transported into the context of Bir and Himachal Pradesh where they were used as interventions or provocations to open up new ways to consider Social Design and 'design for development' approaches.

The following are a selection of student outcomes: ‘Biopot’, Figure 4, a project that addressed social and environmental issues in Bir through the creation of a community-supported business to reforest suitable local areas with native trees. This project could be considered for NREGA funding; ‘The Plastic Bottle Exchange’, Figure 5, proposes that discarded plastic water bottles, a serious problem in the area, could be exchanged for filtered water in a project that also includes the possibility of corporate involvement in the form of Corporate Social Responsibility (CSR); ‘Card Projector’, Figure 6, is a project concerned with the strengthening of bonds and relationships between local communities and families and the reviving of local traditions and history through the distribution of an open-source kit that includes storytelling cards and a DIY slide projector as tools used to facilitate community-led events and celebrations; ‘Conductive Rocket Stove’, Figure 7, is a design for improving the means of cooking in Bir. It is an open-source design that would be made locally from local materials. Through consultations in the Intensive period it was found that this design could have strong aspirational aspects for younger members of the Bir community and could lead to further changes in kitchen layout in addition to the original intent of reducing cooking smoke.

Figure 4. The Biopot project

Figure 5. The Plastic Bottle Exchange project

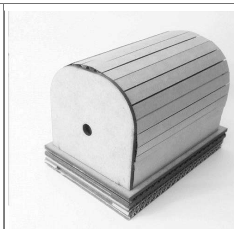

Figure 6. The Card Projector project

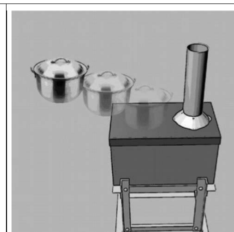

Figure 7. The Conductive Rocket Stove project

9 OBSERVATIONS AND REFLECTIONS

The inclusion of visiting academics as experts into the concept generation and testing phase bought a discernible rigour and richness, in terms of contextual relevance and usefulness, to the student's outcomes. It also improved their understanding of the geographical context and how to design for it. This experience provided an insight into how 'design for development' studios or courses may be able to offer innovative ideas or solutions even if it is not possible to physically visit the sites that are being designed for. The collaboration and connection that is possible between the academics from different Universities through this type of studio means that ideas and teaching methods and styles can be shared and, if suitable, transferred between and incorporated into the other design courses and programs. Finally the input and guidance of the experts enabled the Australian students to design 'to their strengths', that is, in the way they had been taught to design for an Australian context, while ensuring that their design outcomes would be suitable for the remote context of Bir.

10 FURTHER WORK

The approach used in the Deer Park Studio proved to be useful in teaching 'design for development' studios for location remote from the studio location. However further research, through teaching, could be undertaken to see if this could be a useful approach generally as well as specifically. That is, if experts are embedded into a design studio for a short time, regardless of the brief or context of the studio, could similar results be expected? This would be more easily tested on a local scale, using local experts, and could provide insight into how expert knowledge and experience could be incorporated into design studios to improve the outcomes they produce.

11 CONCLUSION

The Deer Park Studio was a successful transnational, 'design for development' and Social Design studio that led to contextual relevant and useful outcomes even though the students designed in a location remote from where they were designing.

The approach of embedding 'experts' into a studio through an Intensive phase was very successful for the Deer Park Studio and further work into this approach would be worthwhile.

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ARE DESIGN-LED INNOVATION APPROACHES APPLICABLE TO SMES?

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ABSTRACT
This study analyses the design discourse and approaches in order to identify whether design-led innovation approaches are applicable to SMEs. It discusses the number of concepts that are widely used in design including design-driven innovation, design thinking and user-centred design to identify to what extent these approaches are derived from the findings about SMEs, take SMEs' characteristics into consideration or meet SMEs' specific needs.
To explore SMEs' characteristics and design and innovation, not only literature but also a series of interview conducted with SMEs (n=8) and designers (n=9) were consulted. To reflect design innovation discourse, the core literature on design innovation and a number of audio-visual materials that are publicly available were also analysed.
It has been found that most of the innovation approaches are exemplified through large enterprises and multi-nationals. Findings indicate that several design innovation concepts encourage businesses to understand their users who can provide valuable insights informing the design process. However, SMEs often have close relationships with their customers, and they already integrate these insights to their innovation processes. Note that SMEs do not incorporate such information into idea generation process systematically. Most of the knowledge within the company is tacit. Thus, design innovation should focus on articulation of this knowledge and integrating into the innovation process. A barrier to innovation is SMEs avoid experimenting due to the risks involved. Rapid prototyping emphasised by design thinking provides a low-cost opportunity to explore whether the new ideas will meet the needs and requirements and address some of the uncertainties involved. Since it is cheap and quick, it is relatively a safe way to address the uncertainty of innovation. Therefore, this aspect of design thinking is applicable to SMEs' innovation processes.

Keywords: Design thinking, design driven innovation, innovation, SMEs.

1 INTRODUCTION

Small and medium-sized enterprises (SMEs) represent over 99% of all businesses in the UK and in Europe. Yet, the number of studies on innovation management in SMEs is relatively smaller compared to those on innovation management in large enterprises [1]. Concepts and theories related to innovation are not always valid for small businesses. In the last decades, scholars have highlighted that SMEs and large enterprises innovate differently [1], [2], [3]. Equally, SMEs' design needs and design capabilities are different than large enterprises.
Design innovation has become the focus of many scholars, educators, practitioners, regional governments and design institutions. Design scholars and practitioners encourage a better exploitation of design by taking a strategic approach. Approaches such as design thinking and design strategy which focus on using design as a strategic business tool rather than developing discrete services and products for business have created considerable interest. 'Intuition', 'creativity', 'holistic' and 'lateral thinking' are amongst important business values which supplement and even replace the traditional values of business such as rationality and calculation [4]. Despite the intrinsic appeal of the design approaches, they have been hardly adopted by SMEs. Although the problem is often explained by SMEs' hesitation and their lack of knowledge using design methods, the applicability of design concepts by SMEs has been seldom explored.
The research reported in this paper raises the following questions: (1) Are design models and approaches applicable to SMEs? (2) Are these models developed according to the needs and characteristics of SMEs? To address these questions, the paper analyses the design innovation

discourse and concepts. The data collected for the analysis includes primary and secondary data. The primary data was collected through a series of interviews conducted with SMEs (n=8) and designers (n=9) by using a semi-structured interview schedule during 2012-2013. The SMEs selected for this study were based in Scotland and worked in variety of industrial sectors including oil & gas, food, building, aqua, information technologies, sport and manufacturing. According the EU definition, two SMEs are medium sized enterprises (R1 and R2) and six SMEs (R3 to R8) are small sized enterprises. Designers participated in this study were based in the UK and mainly worked in small sized design consultancies and agencies. The emergent primary data was analysed by adopting a thematic analysis method. The secondary data was gathered by using the existing literature on design innovation, a number of publicly available audio-visual materials to unfold the dominant design-led innovation discourse.

The rest of the paper is structured as follows: the first section introduces some of the design innovation approaches such as design thinking [5], design driven innovation [6], participatory design [7] before moving to presenting SMEs' innovation processes, their characteristics and their capabilities based on the literature and interview findings. Understanding these characteristics serves to evaluate whether design innovation concepts help SMEs to innovate. The design rhetoric section presents how these popular design approaches appear in the design studies and audio-visual materials. Final section concludes the paper.

2 DESIGN INNOVATION APPROACHES

The roadmap to innovation using design is exemplified through different approaches. These include human/user-centred design [8], participatory design [7], design thinking [5], [9] and design-driven innovation [10], [6]. The basic assumption of user-centred design is users can provide valuable insights informing the design process. These insights can be obtained by asking questions to users or preferably by direct observation while they are using the product or the service [11]. Participatory design or co-design, on the other hand, blurs the boundaries between creators and users. Users become a critical stakeholder in the design process. It advocates "power to the people", and considers how we can get greater benefits from new co-designing relationships within a network of participants whose roles have been evolving. Design thinking has also been found to be a promising approach to harnessing innovation capabilities of a company [5], [9], [12]. Brown defines design thinking as a human-centred approach to innovation, "uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" [5]. Design thinking encourages experimenting and risk taking [5]. "Fail early succeed sooner" is the dictum of many design thinkers. This experimentation process is supported with low fidelity prototyping. Design thinking has raised great interest and mixed reactions amongst design practitioners as well as design scholars [13], [14].

Both participatory design and design thinking have a user focus to achieve innovation. Verganti problematises the user focus in innovation processes and questions how some companies including Alessi, Artemide, Apple or Bang & Olufsen succeed in the market without being user-centred [6]. To him, the reason behind the success of the abovementioned companies is that they apply design-driven innovation. Design-driven innovation stresses the relationship between the vision of the company and new product meanings. Innovation is based on creating new meanings. These new meanings, messages and languages are diffused in society. "Design is the brokering of languages" [6]. His view alters the approach that is design as being solely driven by user needs or new technologies, new functions i.e. 'technology push' and 'market pull' models. Verganti defines design-driven innovation "as an innovation where novelty of message and design language is significant and prevalent compared to novelty of functionality and technology" [15].

3 SMES AND INNOVATION

SMEs play a vital role in both developing and developed countries for economic growth and competitiveness. SMEs' innovation is critical for economy, yet SMEs confront particular problems constraining their innovation activities. Barriers to economic development and innovation are grouped into internal and external barriers [16]. Internal factors are a result of inadequate internal resources and expertise, such as a limited budget for investment, limited access to skilled labour, catching up with improvements in technological advancements, problems in carrying out marketing and project management activities [17]. External factors are market structure, bureaucratic hurdles and the problem of finding suitable partners to collaborate with [17]. The development of strategies for competition and growth within SMEs are limited especially for the ones that manage their operations on a day-to-day fire-fighting basis [18]. Table 1 summarises the characteristics associated with disadvantage and advantage when they are pursuing innovation and growth. Similar to their larger competitors, SMEs need to be concerned with their market positioning, technological trajectories, competence building and overall organisational processes [19].

Table.1. Summary of SMEs characteristics associated with weaknesses and strengths based on Nooteboom [19]

Characteristics associated with disadvantages	Characteristics associated with advantages
• Lack of functional expertise and the difficulty in hiring full-time specialised occupations for diverse tasks • Difficulty of diverting skilled personnel from day-to-day activities • Limited investment capability, resources on new technologies • Lack of organisational characteristics that enable strategic use and acquisition of knowledge • Ad-hoc management • Short-term perspective	• Dynamic–lean structure • Personality, independence • Informal structure, short communication line and strong leadership • Sharing information quickly • Non-hierarchical structure • Accessibility of top level management • Filling niche opportunities • Customised new products

The interviews conducted in this study also reveal the opinions of SMEs regarding their understanding of innovation. The majority of SMEs believe in the potential value of innovation for improving their competitive position, reducing costs and expanding their customer base. Amongst the SMEs interviewed, incremental innovation through smaller improvements are usually preferred to radical innovation steps (R2, R3, R7).

Table 2. SMEs' approach to innovation

Example quotation	Summary statement
"We've planned to double our profit in the next 10 years. Large part of that is through innovation, so new products, new product introduction." R1, SME non-owner-manager	Innovation is important for growth
"You've got to be careful that you don't become too innovative". R2, SME non-owner-manager	Cautious-avoiding major innovations
"[Innovation is] Obviously doing things differently. But the construction industry is very conservative because it is producing a long-term durable product. If something is tried, tested and proven, we are keen to keep doing that because we know it is safe." R3, SME owner-manager	Important of tried and tested methods
"Innovation is to me when you come up with a new way of doing something that has obviously got benefits so everybody else is doing so. I don't think we do that in how we deliver services. It is more small innovations rather than one big ta-da. It is all about lots of small improvement you can make in how we work." R7, SME owner-manager	Small changes rather than big steps

The main barriers to innovation put forward by the SMEs are a lack of time and resources. The small sized businesses were occupied with day-to-day issues, which prevent them to seize innovation opportunities (R3, R5, R6, R7). The interviewees indicate that because of their busy schedules, they do not have time to reflect and plan ahead and instead they focus on short-term results and easy-to-apply solutions.

> "I think there are opportunities for innovation that we missed a lot in the past because we are so busy fire fighting and just dealing with day-to-day". R6, SME non-owner-manager

> "Everyone is so busy running around to get the day to day work done, they can't look forward and plan what they are doing." R7, SME owner-manager

The majority of the SMEs (R1, R2, R3, R4, R5, R6, R7) approached for this study uses their customers and employees as a source of information and the basis for developing innovation. Often this knowledge is personal and owned by a small number of individuals.

> "Simply, I was born and brought up in the countryside, which leads me perhaps to think a bit differently from people who are from the cities. While working in the countryside, we meet a lot of people, listen to them and hear their needs. You pick up what people tell you basically". R3, SME owner-manager
>
> "I have been working in the market for 20 years. I understand the market fairly well. Not only I am picking up knowledge on that but also if I have a specific question that needs answering, I can actually ask them directly to the market because I know people and companies within the market. It is done by actually consulting people in the market." R4, SME owner-manager

Amongst this group of respondents, the representatives of medium sized companies (R1, R2) reported that they develop ideas for innovation on a systematic basis. These initiatives include the use of an idea-box, internally held meetings and workshops held with external or internal facilitators. The other SME respondents from small sized companies (R3, R4, R5, R6, R7) did not mention a systematic process for developing ideas for innovation. Their expertise is often the source of their ideas. It appears that most of the knowledge within these companies is tacit.

On the other hand, from the designers' perspective, as R16 commented, the focus is on understanding the user, *"They [SMEs] need help, I think they need to understand a lot about their end-users, what their end users need and want. So that's the big, I think*". Similarly, as discussed above, several design-led approaches emphasise the importance of understanding users and customers [20]. In fact, communicating directly with customers to understand their needs and opinions is not a problem for small businesses. They often have a face-to-face relationship with their customers. They comprehend the needs and requirements of their customers. However, it appears that small businesses in particular need to capture information from their customers more systematically for generating new ideas for innovation. Therefore, design methods and tools should focus on capturing and articulating the customer' needs and feedback and then translating this information into the innovation process in a systematic way. The assumption which SMEs do not understand their customers and users may be invalid; thus, user-centredness may not be a ground breaking approach for SMEs.

The interviews conducted in this study indicated that SMEs have a greater tendency to pursue incremental innovations rather than radical innovations. It was clear that SMEs avoid taking risk. Design thinking encourages experimenting and risk taking by proposing 'fail quickly and cheaply to succeed'. Because uncertainty is an unavoidable part of the innovation process [21], by adapting such aspects of design thinking, SMEs can better address the uncertainties of business and innovation processes.

4 THE DESIGN RHETORIC

Since design innovation has become the focus of many business and design scholars, practitioners and regional governments, there are several online multimedia that promote design innovation and the role of design in business. The Industrial Designers Society of America has recently commissioned Mormedi - a Spanish design consultancy- to produce a video about the main challenges the design industry in Europe. The video presents the viewpoints of leading companies such as BMW, Bosch, Orange, Philips, The Foundry and BBVA. Amongst these different industry sectors such as automotive, consumer electronics, banking or telecommunications, there are no standpoints of SMEs to represent design challenges [22]. Similarly, the UK Design Council's 2010 video on design's role in innovation only features big corporate leaders [23].

If the academic design literature focusing on design-driven innovation concepts is explored, it can also be noticed that the concepts draw upon the observations of large enterprises including Apple, 3M and Dyson and build on interviews conducted with designers from leading design-led companies such as Alessi and IDEO. For example, Verganti states,

> "Consider for example the diffusion of coloured translucent materials from home furniture to computers (a linguistic exercise that let the Apple I-Mac speak the language of home rather than office. In this case Jonathan Ive, the VP of design of Apple, with previous experience in domestic products, acted as a broker of languages from households to computers)" [6].

Likewise, in his book, he suggests, "Design-Driven Innovation unveils how leaders such as Apple, Nintendo, Alessi, Whole Foods Market build an unbeatable and sustainable competitive advantage through innovations that do not come from the market but that create new markets" [15]. Equally, to Beverland and Farrellyi, design-led innovation means that design plays a strategic and central role in innovation. They gave examples from companies such as Apple, Vitra and Dyson [24]. The design process generates innovations that have been unforeseen by the market. Brown provides no mentions to SMEs while introducing design thinking concept [5]. The great emphasis on large enterprises and corporate leaders on these publications poses the question if design innovation concepts are derived from the findings about SMEs. These abovementioned examples still do not fully illustrate how many times we heard of Apple and Dyson when design-led innovations are mentioned. To some extent, using well-known companies to create some sort of recognition is understandable. Nevertheless, these representations also frame the language in such a way that leaves SMEs invisible in the design innovation discourse and leads to questionable assumptions amongst designers.

5 DISCUSSION AND CONCLUSION

This paper has argued that whether design-led innovation approaches are relevant to SMEs' innovation processes. It looked at SMEs' core competencies and main barriers to innovation, which were then compared with the features of mainstream design approaches. The findings demonstrate that many SMEs avoid taking risk; therefore, approaches such as design thinking encouraging experimentation, addressing uncertainty and highlighting cheap prototyping are relevant to SMEs and help them build such capabilities. On the other hand, SMEs have close relationships with their customers and users, and they device their customer relationships and observations to generate new innovative ideas. Concepts focusing on understanding users seem to be better suited to large enterprises than SMEs. However, the findings illustrate that most of the knowledge base within SMEs used for innovation and growth is tacit in nature and shared by a small number of people in the company. Design innovation methods therefore should support SMEs to externalise their tacit knowledge.

It has been found that most of the innovation approaches are exemplified through large enterprises. The types of videos, papers and blogs that mainly represent the perspectives of large corporate leaders and multinationals add up over time and affect our understanding of the way in which design should work and help companies. Eventually, this strengthens the invalid assumption that is design-led innovation for large and small firms are alike. These perspectives also have implications for the design education. Design graduates often have to work with SMEs within the current economic climate. This research concluded that viewing SMEs as microcosms of larger companies is not helpful; distinctive characteristics of SMEs should be recognised to understand how SMEs learn, design and innovate. SMEs intrinsic characteristics should be incorporated in the design education, the design theory and the design practice, and the expectations of large enterprises should not dominate the development of the design field.

This research has identified that not all aspects of design innovation approaches are applicable to SMEs. This conclusion matches some of the existing research. For example, Deakins and Freel [18] and Zhang et al. [25] draw attention to the fact that often learning models are developed according to the needs and features of large organisations. Hence, these models are often not applicable to SMEs. For instance, Deakins and Freel claim that considering the size of small firms, theories improving communication can be ineffective in SMEs, as communication with a small number of employees should not be an issue for an SME [18]. To Deakins and Freel, the concepts and theories that recognise the impact of uncertainty in learning and development, such as Schumpeterian dynamic approaches, are better suited for SMEs [18].

While aiming to understand if SMEs' requirements are addressed by design methods and approaches, it should be noted that SMEs are not only different in size, sector, technology and R&D level, age/lifecycle and geographical location, but also in their individual dynamic and informal knowledge [26]. Over-generalising their inherited weaknesses and strengths might also be problematic while evaluating design approaches for innovation. This research is based on the findings that are derived from the literature and qualitative data derived from a limited number of participants mainly representing Scotland. Future research might consider validating some of the conclusions with quantitative data, such as surveys.

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RAISING OUR GAME: CREATING NEW LEARNING EXPERIENCES WITH RESEARCH COLLABORATIONS

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ABSTRACT
Within the University sector, there has been concern expressed in recent years over the accreditation of alternative higher education providers to deliver degree programs. This presupposes that the two sectors would be in direct competition for the same students with providers offering similar programs and content, and catering to students with similar learning styles for comparable outcomes. Arguably, if a University is failing to provide a learning experience that is significantly more elevated and substantially different to one that is offered by an alternative higher education provider, then it should be re-evaluating its own practice rather than trying to eliminate the opposition.
Product Design programs have undergone a contracted evolution since their academic inception following the Industrial Revolution. Therefore, they are arguably best placed to lead an evolution of University education as they are less hampered by the weight of historical expectation than traditional academic disciplines. This paper is a reflective opinion piece that proposes new practice to provide innovative, high order thinking learning experiences inspired by cutting edge collaborative practice between international University research partners. This partnership is based on an aspiration model of authentic collaboration between product design and engineering, in a health and wellbeing context. It suggests a way forward that clearly differentiates and enhances University Product Design education for a next generation research design education nexus.

Keywords: Transformative, collaboration, innovation, eLearning, transdisciplinary.

1 INTRODUCTION

According to Scott, Professor of Higher Education at the Institute of Education in the UK, institutions that started as Colleges of Advanced Technology in the UK, such as Surrey and Bath Universities, survived the transition to University status whilst maintaining a strong commitment to world-class Engineering and Technology. However, as UK polytechnics were universally given University status in 1992, Scott argued it was surely inevitable there would be problems. In a 2012 article in the Guardian newspaper [1], Scott described how the UK Government in 1992 saw a revised role for all universities "as business-facing institutions producing graduates in vocational disciplines and applied research," but he challenged the understanding of the Ministers at that time of a definition of those labels and their implications for University education. With widening participation and an aim to increase the percentage of school leavers attending Universities throughout the nineties, there were significant changes to the higher education remit that impacted all Universities, including those that were long established. Even with the newly created Universities taking on the 'heavy lifting', as he phrased it, Scott argued that rather than polytechnics becoming Universities, in fact it has been the other way around, and it is the 'socially engaged and entrepreneurial University that has become a model for 21st-century higher education', rather than the research-based, classical education model that formerly characterized Universities becoming the profile of the former Polytechnics.
In Australasia, the higher education system is currently facing a further re-evaluation of status as TAFE colleges and Private Colleges increasingly offer degree programs accredited by proactive Universities in the sector, such as the University of Canberra. Open access online programs, such as massive open online courses (MOOCs), as well as an increase in online degree programs run by established higher education providers through the Open University system, challenge prospective students to interrogate what is being offered by the different facilities and how it suits their needs. However, the reality is that even in the UK, school leavers born in the late nineties, are unlikely to

differentiate between ‘so-called Shakespearean, red-brick and civic universities’ [1], and with the myriad of degree offerings and suppliers, not necessarily comprehend what the differences in providers might mean, or even value any difference between the private college sector and the established degree provider Universities. The second reality is that without an imperative for their lecturers to undertake research, Private Colleges are better able to be more student focused. It is therefore relevant for higher education providers to question what prospective students are basing their choice of education pathways on. The issue discussed here is whether Universities are doing enough to ensure informed decision-making by students about those additional learning elements housed in University education that can impact the students’ learning experience. More fundamental, perhaps it is to consider if Universities are genuinely maximizing what they can offer within an educational experience to the benefit of student learning and are they providing a clear point of difference to the private providers, both in reality and in the eyes and understanding of their customers.

If an applicant is driven by a desire to achieve a basic, current-industry aligned Product Design qualification rapidly in order to improve their immediate employment prospects, then potentially an accelerated program of study, with a four-semester year and industry based / connected lecturers not involved in research, whose sole focus is teaching and local industry practice, could potentially meet their needs. If this is the case, then arguably there is no obvious impediment to private colleges taking on this role for these customers. This should be a concern for Product Design as a discipline, especially in an increasingly competitive environment. More than 150 private providers now offer degree programs in Australia, with a significant impact on traditional higher educational models. In addition, for any faculty member still insistent that the provision at a University will be seen as ‘better’ by prospective students, the comparative costs are telling – attending private providers may be up to three times the cost of a University, and yet their student body is still growing. As an applied program that is still predominantly practice led and industry focused, and one that has only effectively become a University level discipline since the Polytechnics became Universities, there is an imperative for the Product Design academic discipline – more than most disciplines - to ensure significant differentiation between what is offered at University and through competing institutional models.

2 POINT OF DIFFERENCE

Although Product Design as a University discipline evolved out of technical colleges, it should now be mature enough to shake off any academic cultural cringe, and stop trying to compete with traditional disciplines on their research terms, rather than one driven by Product Design researchers themselves. Product Design researchers should objectively rethink the practices that developed out of commercial practice driven teaching strategies conceived during the discipline’s early academic years. University Product Design education should be - and for commercial viability needs to be - markedly different then that available through a private provider and it has never been more timely for that difference to be clarified and re-enforced. As an academic group, Product Design educators need to seriously review and revitalise their teaching practice to reflect the current academic profile of University lecturers; be informed by the cutting edge research in the discipline; be connected by international collaborations formed through dedicated conferences and engage students based on innovations in learning and teaching developed through enhanced teaching scholarship.

There is a broad challenge for all disciplines in Universities in helping prospective students to recognise and appreciate:

1. Faculty qualifications - what qualifications do Faculty members have that are relevant to the students? Do prospective students value staff qualifications and do they understand what these mean? Are they aware of staff publications and do these have any relevance for them?
2. Research practice - how much dissemination of research practice to students and prospective students takes place? If thoroughly understood, would this aspect of the lecturers work be valued in its current form by prospective students, or seen as a distraction from teaching?
3. Lecturer’s informed, international viewpoint - particularly in relation to school leavers. How valued is an internationally informed opinion and how would it be communicated and utilized?
4. Innovative practices in learning and teaching - understanding the impact of pedagogy and how differences in learning experiences affect lifelong learning. Are these innovations being maximized within the discipline, and is there evidence of a difference in graduate attributes?

These questions are more immediate for the applied disciplines and the fundamental question is how Product Design University education can offer a learning experience that demonstrates excellence and relevance in education based on the most significant points of difference for Universities listed.

3 A NEW PARADIGM

As the Product Design academic discipline becomes more established, a growing recognition of the value of the involvement of lecturers in real world design project collaborations as valid qualitative research outputs, is gradually allowing the fundamentals of the discipline to be reasserted. However, the lack of perceived value of this work to the prospective student themselves in comparison to the value of an offering with overtly industry focused / based lecturers needs to be addressed. If Product Design education in a University environment should be providing a more challenging, transformational learning experience, then it needs to seriously raise its game. Otherwise not only will students drain out into the private sector, but Product Design educationalists at Universities will miss an opportunity to create genuine learning experiences that prepare students as effectively in the future for the changing work environment they will be entering, as they were in the past. As the quote from the Sicilian classic, 'The Leopard' suggests: "If we want things to stay as they are, things will have to change" [2]. To provide graduates who are equipped to contribute to the world around them, then as the world changes, to provide equally appropriately prepared graduates, design education has to change. Design graduates are entering a design environment that is increasingly interdisciplinary and concerned with complex problems and systems. The challenges facing designers today working on situational design problems extend far beyond the derivative design tasks of the commercially constrained design practices that dominated the profession last century: "Collectively, designers are seeking to enhance human health, prosperity, and comfort while diminishing the conflicts between people and the global ecosystems we inhabit." [3]. In order to rise to the challenge of providing future designers with an outlook and understanding that prepares them for these aims, design educators need to draw directly on their own expertise in working on complex research projects and then, based on that expertise, design related educational experiences: "The researcher seeks to empower, transform, and emancipate individuals from situations that constrain their self-development and self-determination" [4]. Designers, by definition, work on projects where the outcome is not known and lecturers that inculcate the students with this way of working support their development. By not only informing their educational practice with their research, but more fundamentally designing learning experiences that involve students in research themes pertinent to the lecturer's own area of research maximises the abilities, experiences and enthusiasms of those lecturers for the benefit of the students. Rethinking pedagogy in this way provides the basis for meaningful learning experiences for students and clearly, and significantly, differentiates it from that offered by the private providers. This establishes an educational intent that looks beyond the immediacy of current commercial practice and towards enhancing human knowledge in the area of Product Design more broadly: "The primary purpose of applied research (as opposed to basic research) is for discovering, interpreting and developing methods and systems for the advancement of human knowledge on a wide variety of scientific and humanitarian matters relating to our world" [5]. In proposing a new model of Product design education, the aim is to provide mechanisms to create and support authentic learning experiences that break with outdated modes of learning, and overtly maximise what can be offered as significant learning supported by research expertise.

4 CHANGING PRACTICE

Innovations in pedagogy that create step change, rather than incremental change, require creative thinking. There are examples in education that provide direction, such as the Thomas Telford School in the UK: The Thomas Telford [6] was founded in 1991 by Kevin Satchwell (now Sir Kevin Satchwell) specifically to provide an effective educational model for children with a history of absenteeism and to do so it radically revised conventional educational practices and the organization of learning. The traditional school model was failing these pupils as the curriculum continued in their absence so that when they did attend, they were out of sync with other students and had missed important elements of the subjects. Satchwell proposed a schools system based on the individual. Each pupil follows an individual study plan that operates irrespective of his or her peers' progress and of year levels. Teachers focus on delivering their area of expertise in classes designed to allow for students to map a learning pathway through them. A revolutionary proposition at the time, this school now attains high outcomes and has been replicated throughout the UK and provides the blueprint for a very new way of organizing school education. If this kind of objective and innovative thinking is applied to University Product Design education, then a new model could emerge that capitalizes the excellence in University research for the benefit of the students, is disengaged from the conventions of current educational organization – such as weekly lectures and seminars or studios run by individual lecturers – and maximizes the collaborations that are already in place as part of the integrated network Product Design lecturers have developed worldwide to address complex research projects in expert teams.

From trying as individual Product Design University departments to address all aspects of a research project in house, it is now possible – in fact it appears a marketing necessity – to identify a Product Design program specialisation that can be the basis for local and international research collaborations. Multiple Product Design lecturers, along with collaborators from related disciplines, such as Engineering, now commonly work together, bringing distinct profiles and specific research focus to the activity. This is where the point of difference between private providers and Universities is very clear. Lecturers at Private Colleges do not have the opportunities to collaborate across disciplines and across Institutions to provide the research informed education that University lecturers do. University Product Design educators are in a unique position in the market to offer learning at the research design education nexus and provide an inspiring, exhilarating learning experience beyond what is possible in non-University, ground level education. The example below suggests how this could be achieved.

4.1 Towards a research education design nexus

"Education should reflect on its own paradigms, and envision what types of designers society will need in the future" [7]. The Product Design world has evolved since the changes to the higher education provision in 1992. There has been a globalization of markets, increased user / designer communication and a development of advanced manufacturing technologies that allow for design creativity and bring together computer science and user-centred design. Initially globalization appeared to lead the world into an amalgamation of markets and the mass production of mass-market products, to the detriment of the individual. However, in the last five years there has been a shift in focus, with a rapid rise in design for the individual based on a web of interconnected developments. Web 2.0, for example, where users and designers can interact more directly via the Internet is making an impact; designs that can be bespoke through an increased accessibility of electronics, and then the rise of digital fabrication as a realistic option as additive manufacturing (3D Printing) which began to mature as a process. This resulted in a personalization of product design that is a focus for many design lecturers and opens the door to cross-disciplinary collaborations and innovative areas of design research. This particular example of proposed innovative educational practice draws on these developments and is based on a research collaboration between Product Design and Engineering lecturers at Auckland University of Technology in New Zealand and Griffith University in Australia. It works towards a model of practice for significant, transdisciplinary learning that maximizes the research expertise of Product design and Engineering University education and is built around the AUT / Auckland Hospital Design for Health and Wellbeing Lab shown in Figure 1.

Figure 1. (a) (b) and (c) AUT Auckland Hospital Design for Health and Wellbeing Lab (S.Reay)

There is a synergy of expertise between the design thinking for clinical applications work in Product Design research at AUT in the Design for Health and Wellbeing Lab, the design education for engineering students drive in the Engineering departments at AUT and Griffith University, and the research into advanced technology applications for clinical practice in Industrial Design research at Griffith. The collaborators share research, and work on cross-disciplinary objectives that transcend faculty divisions and the physical distances between the researchers involved. In this case, Design for

Health and Wellbeing provides the vehicle for collaboration that respect the individual specialisations of each lecturer in cutting edge research to create an enhanced synergistic response to the complex issues the context provides.

The existing paradigm is that this research informs the teaching practice of each department, with design approaches taught in the AUT Engineering program, design thinking embedded in the AUT Product Design department, CDIO and creative engineering taught within the Griffith Engineering program and advanced technology a driver for curriculum in the Industrial Design program at Griffith. Students do benefit from the research the lecturers undertake, but for them it is localized to the lecturers they work with in conventional studio based courses in each department. The transdisciplinary research experience of the lecturers is not reflected in the curriculum or pedagogy of the individual programs. But what if it was? What would that look like? How could a University education in Product Design be elevated by the research collaborations of the lecturers to be directly informed by that cutting edge and cross faculty and cross campus research?

If, as predicted, there are to be fewer students achieving a University entrance score in 2020, and with increased competition from Private Colleges, then finding the answers to these questions may provide the basis for a new paradigm for Product Design education in breaking the conventions of current teaching and lifting the game of the academic discipline to lead the practice of other disciplines, rather than trying to emulate outdated modes of educational thinking, or competing at the lowest level for mass education divorced from best practice in student learning.

Imagine a University semester long course that immersed the students in the research practice of the lecturers. Imagine students working across Universities and across disciplines to navigate their project pathway informed by the expertise of each lecturer and department. Imagine them working, much as in the Thomas Telford model, to maximize their learning and in conjunction maximize the individual expertise of the researchers, who would be freed to become the consultative expert who provides lectures relating to their expertise and perspective of an overarching research theme in the same way as the Thomas Telford team do, and where the support for a student would come from the person best placed to help them, not just the closest. The student experience would be released from the chains of conventional learning based on imposed uniform organizational structures that bear little relation to the reality of design ideals and support proactive, empowered learning.

The barriers to implementing this type of learning activity are considerable. For a start, spending time at another University, which may be overseas, would add to the cost for the students concerned, but with the rise in Private Providers in spite of their higher costs, students have already proven themselves willing to invest in their education if they see the value of it. Furthermore, many students do choose to take on study periods overseas. From the University point of view, it would require revolutionary thinking in relation to every aspect from assessment to administration. However, the potential benefits are equally significant. From a marketing point of view, University education would lift itself out of the doldrums of direct competition by providing a clear point of difference, and one that finally maximized the research imperative of the lecturers, and the network of cross disciplinary and cross campus collaboration, for undergraduate education. This type of educational model would provide that overt value to prospective students, bringing the time and effort lecturers invest in research back into the domain of the student experience and would be directly relevant to the quality of the educational experience.

5 CONCLUSION

"We need to rebuild systems themselves. In doing that job, new designs, innovative engineering, and community technologies….the future demands that we not only improve the new, but restore and reimagine what we already have" [8].

Current University Product Design education does need to take a good, hard look at itself. It is no longer new, or in transition, and if it is to be regarded as first class, educators need to decide how its performance should be characterized. In doing so, Product Design University education needs to maximize its differences, and overtly develop its academic discipline, with a defendable identity and integrity that provides the basis to develop new learning practices that maximizes what it is, can be and should be. Dee Fink [9] describes 'significant learning' as changing students' perspectives rather than adding to their knowledge base, and challenges tertiary educationalists to interrogate the learning experience they provide to ensure students are engaged in transformative learning that alters their very outlook and understanding. The model of accelerated learning offered by industry based private colleges does not provide a model for transformative learning. The point of difference for University education in an applied discipline is in looking up and out, rather than at the immediate and the past. This requires creating a proactive curriculum, rather than a reactive one. Education that provides new direction for the discipline, refreshes industry practice and hauls it up over the barriers of current practice and convention and launches it on a new path informed by the cutting edge research. This will be found in the foundation of lecturers with international and cross-disciplinary collaborations, knowledge of global environments and informed by conference participation. It should be characterised as innovative, refreshed, pertinent learning fuelled by advances in learning and teaching research informed from the University. If the discipline is to respond to the changes outlined by Fuad-Luke in Design Activism [10] as needed for positive future design practice, then lecturers have to start to build and develop scaffolding for 'cohesion and capacity' to build 'resilience and enable future adaptation', by creating proactive learners, those who can step back from the immediate and look more broadly, more openly, more creatively at challenging situations and make positive contributions to a collaborative, informed design approach. For example, Eindhoven Department of Industrial Design, organises its workspaces thematically to promote shared learning and shared expertise and Hummels, in Open Design Now [7], advocates that "Faculties, departments and schools have to think both physically and virtually about workspaces that enhance collaboration" with a hybrid digital and physical environment that is "always available all over the world" but it still anchored to a single base point and therefore restricted to the influence of the lecturers in that place and the research focus there. This model as a provocation proposes elevating themed learning outside the boundaries of the disciplines, the faculties, the Universities and even individual countries to create innovative pedagogy based on a bouncing ball project approach where the students bounces rather than the project.

Product Design education has spent too long trying to be accepted, too much energy adapting pedagogy and research practice to ways other disciplines can recognise in a drive to be accepted, but the academic discipline is now mature enough to stop and take stock – and the rise of the private providers provides that impetus. Design and Engineering are both concerned with looking to the future and now is a time to come together and make their relationship work effectively - not as an uneasy partnership where elements of each others practice are subsumed into the disciplines, but with a transdisciplinary vision that shows a new way forward for new learning practices in Universities that differentiate them from private providers and supply students with a truly transformative education based on a research education design nexus. A potential next step would be to design short collaborative curriculum experiments, building on the design for health and wellbeing research network, to bring researchers and students together from a range of locations and disciplines around a common problem. This would highlight the challenges and opportunities for future collaborations and provide starting points for renewed educational practice.

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Chapter 17

Research

STUDENT DESIGN ENTREPRENEURSHIP, FROM CONCEPT TO RETAIL IN NINETY DAYS

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ABSTRACT
The intent of this paper is to outline the need and benefit of integrating design entrepreneurship training in product design education, and to provide a case-study for how to create an educational experience that synthesizes the many aspects of design entrepreneurship through a participatory action-oriented studio project.
In recent years, access to manufacturing, financing, and distribution has changed dramatically, and this is having a significant effect on how new products are being developed and marketed. This has resulted in a growing opportunity for smaller-scale projects involving a small number of adaptable individuals with flexible skillsets. Design students with training in entrepreneurship are uniquely qualified for this type of work, empowered to produce and market their own designs or work with others to start a niche product company.
To prepare students for this changing marketplace, it is helpful to create synthesized participatory experiences through which students apply the concepts and skills associated with design entrepreneurship. This paper introduces a hands-on project that has been utilized for two years in an undergraduate Product Design curriculum, in which students work through the entire process of product development, from concept and research, design development and manufacturing, branding and marketing, to packaging and retail. The project culminates in a business plan and a retail event. Such training has the benefit of preparing students for future work, either in industry or as an entrepreneur, and deepening their understanding of the role of Product Design in the larger business context of new product development.

Keywords: Design entrepreneurship, new product development, crowdfunding.

1 CHANGING CONTEXT FOR NEW PRODUCT DEVELOPMENT

To be a successful design entrepreneur one must have the skills of a designer and an entrepreneurial business manager. However, Product Design is commonly taught as a separate skillset, which is one part of the larger context of new product development (NPD). Milton and Rodgers outline the four major components of NPD as: Research, Design (including engineering and industrial design), Marketing, and Manufacturing [1]. In practice, these professions are usually represented by different members in a product development team, or sub-groups within a larger product development organization.

This model has worked well for large organizations and larger-scale projects, and design education has commonly focused on positioning graduates within this context. However, there is growing demand for smaller-scale entrepreneurial projects involving a smaller number of adaptable individuals with flexible skillsets. The *design entrepreneur* demands a different model of training. Gunes defines design entrepreneurship as "…producing and marketing the intellectual properties of a viable concept in terms assuming risks, financing, marketing, and managing. It is not just creating innovative product ideas by conventional design skill set but also organizing and operating a plan through idea into physical profitable product by initiative skills." [2]

1.1 Changing Context:

In recent years, four major trends have changed how NPD occurs: greater access to manufacturing, falling cost of digital fabrication and prototyping resources, crowdsource methods of financing, and decentralized distribution through companies like Amazon. First, for manufacturing, anyone can now search sites like Alibaba to source materials and manufacturing resources, where this was previously specialized knowledge limited to those in the field. Second, the trend in affordable desktop digital manufacturing has drastically lowered the cost and barriers to entry for individuals to create 3D prototypes, while digital fabrication has significantly accelerated the pace of new product development [3]. Third, an array of crowdfunding financing models (e.g. Kickstarter, Indiegogo) have made it possible for small start-up companies to finance their businesses independently, rather than seeking funding through traditional models such as bank loans or venture capital [4,5]. And fourth, online shopping and distribution logistics are being facilitated through Amazon and other third party companies, externalizing logistics and reducing bricks-and-mortar overhead [6].

These four factors combined have made NPD faster, more accessible, and more affordable. This has created a new wave of design entrepreneurs, who combine design thinking and startup culture to create new approaches to entrepreneurship [7]. And this trend presents a very different professional landscape, compared to the past industrial structure that created the field of product design.

1.2 Design Entrepreneurship as a career path

For current students in Product Design, these changes open up opportunities for a new type of career path: design entrepreneurship facilitated by newly democratized access to manufacturing, finance, and distribution. In a highly competitive job market and lagging economy, this can become an appealing professional path. Micro-marketing avenues like Kickstarter or Quirky have shown that there are more options available to industrial design graduates besides working for large manufactures or design consultancies [8]. Students can go on to produce and market their own designs, or work with peers to start a niche product company.

1.3 The adaptable skillsets of design entrepreneurs

Entrepreneurial enterprises typically require individuals or small groups of nimble creative personalities that can play many roles in a given project. L. Ball's research on design education highlights how design graduates are uniquely qualified for this type of work: "The hands-on, problem-solving approach of craft/design higher education equips graduates well, as it produces flexible, adaptable entrepreneurs, but so often these valuable processes are not articulated."[9] Our goal is to articulate this adaptable value, and to make it an explicit part of design education through practice.

Entrepreneurship may not be the chosen career path for every design graduate, however Ball indicates that most graduates will work in a small or independent business at some point in their career [10]. Therefore, it is believed that entrepreneurial skills can enhance the already adaptable skillsets of designers, improving their job prospects in the changing marketplace described above. Training in this area better prepares students to contribute to a small start-up or engage in a multi-disciplinary team. Furthermore, a designer with entrepreneurship training makes a stronger member of a product development team in a larger organization. In *The Design Entrepreneur*, Heller and Talarico explain, "The designer as entrepreneur actually has an advantage over the non-design entrepreneur who must employ others to manufacture, package, brand, and promote. Even if the designer subcontracts these tasks to others, he does so from a position of complete understanding of the media and materials involved."[11]

2 STRUCTURING A PARTICIPATORY ENTREPRENEURSHIP TRAINING EXPERIENCE

While much is written about the types of content that should be included in design entrepreneurship education [2,12], there seems to be less written on *how* to implement it. Therefore, the goal of this paper is to provide a case study for how design entrepreneurship can be taught with minimal change to an existing Product Design curriculum.

Our intention is not to advocate for a new degree program. There are quite successful masters programs in Design Entrepreneurship (e.g. SVA in NY), and many entrepreneurship programs at the Bachelor's level and above. However, our interest is more in integrating design entrepreneurship in an existing Product Design curriculum. The intention is to foster design entrepreneurs who are designers first, with some of the essential skills of entrepreneurship.

2.1 Hands-on project

In order to develop and effectively internalize the skills of a design entrepreneur, it is recommended to pursue a pedagogy of learning through doing. Preferably, this is done by creating an in-depth synthesized participatory experience through which students apply the concepts and skills associated with design entrepreneurship to an actual product. Emil Levy, of the Institute of International Education outlines four 'Essential Tips for Designing Successful Entrepreneurship Education Programs', and the first is: "Base your program on experiential learning." He further explains, "[E]ntrepreneurship can only be taught through hands-on projects where participants create their own ventures and participate in live case studies."[13]

This guideline for entrepreneurship education is also reflected in Rasmussen's survey of four Swedish university programs, in which he concludes, "In an educational setting the students should meet and internalize a realistic business concept from the outset. Further, they should be operationally involved in real business contexts."[14]

2.2 Go to retail

Design students are commonly trained in research, problem identification, ideation and prototyping. However, for design entrepreneurship to really take hold, it is helpful to follow the product through to retail. It is necessary to go beyond conceptualizing an entrepreneurial project, and go through the entire process of design development, manufacturing, branding, packaging, and retail. This effectively closes the loop of designer-to-end-user in order to validate the design idea in the marketplace. As Heller and Talarico explain, "Just making some fun doodad and putting it on a shelf is not enough. The design entrepreneur must take the leap away from the safety of the traditional designer role into the precarious territory where the public decides what works and what does not."[15]

2.3 Manage project scope with Peter Drucker's Do's and Don'ts

To establish some initial guidelines, it helps to begin with Peter Drucker's "Do's and Don'ts" from his book *Innovation and Entrepreneurship*. Following these guidelines helps to increase the likelihood of success and keep the project within a manageable scope for a relatively short-term academic project.

Do's

- *Begin with the analysis of opportunities*
- *Go out to look, to ask, and to listen.*
- *Keep the innovation simple and focused.*
- *Start Small.*
- *Aim at leadership*

Don'ts

- *Don't try to be clever.*
- *Don't diversify, splinter, or try to do too many things at once.*
- *Don't try to innovate for the future.* [16]

3 THE 'DESIGN STORE' PROJECT (A CASE STUDY)

The 'Design Store' project was created as a studio-based design entrepreneurship project in a Senior-level (4th year) course. This was a semester-long (16 weeks) project for a 5-credit studio course. At this level students are expected to apply their design skills to a more in-depth long-term project, and synthesize what they have learned in other courses towards a single design effort – from design research, to ideation, drawing, CAD, prototyping, etc. Essentially, students have established a range of design skills, and this project was intended to apply those to a design entrepreneurship effort.

3.1 Managing Project Scope

One of the greatest challenges is to complete this type of project in a single academic semester. Given the timeframe, it was necessary to keep the projects fairly small and simple, following Drucker's guidelines above. The real benefit for students was being responsible for the whole picture, from product concept to packaging and retail. And the scope of this project allowed students to address that big picture for a small product. This was handled by giving a specific project brief that focused the students on small-scale products.

3.2 Brief

The first iteration of this project was titled *Accessorize/ies*, and was based around the concept of 'accessorizing accessories', challenging students to design products that enhance already-existing products. This was done to limit the scope, while also asking students to design for a specific context with established constraints.

The second year the project was run, it was reframed to focus on outdoor activities, and the project was titled *Outside Experience*. The goal was to take advantage of the geography and marketplace near our university, a mountainous area popular for winter and summer sports, and to design accessory products for those activities. This brief was also intended to deepen the investigation/research portion of the project and to engender more inventive solution-based products, moving away from some of the kitsch impulse-purchase products created during the previous year.

3.3 Deliverables

A series of key deliverables helped to broaden the learning outcomes for the project and deepen the students' experience.

3.3.1 Produce 20 units and retail for under $50 each

The project brief asked the students to design a product which one student could produce in a batch quantity of 20 and retail for under $50 per unit. Individually, students were required to define a market need, design the product, develop production, create the branding and packaging, and make a point of purchase display. This structure was based on the instructor's prior experience selling work via the Designboom Mart at the International Contemporary Furniture Fair in New York, which follows a similar model: asking about 20 designers to bring at least 20 units of a self-produced product that retails for under $100.

3.3.2 Write a business plan

Because the goal of this project is to encourage students to be entrepreneurs, and to create viable mass-market products, students were tasked with creating a business plan for their project. For that, we partnered with faculty from the business school on our campus. A Professor of Management was a guest speaker in the class and introduced students to the book *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers* by Alexander Osterwalder and Yves Pigneur [17]. This text also provides a very handy and concise canvas for developing a business model. Each student then worked with this canvas to begin their business planning efforts.

The business planning component helped students gain a deeper understanding of the role of design in business, and face the humbling reality that design is only a small piece of the larger product development puzzle. By learning about business planning, students also became more comfortable with the terminology and language of business, a benefit for communications with future clients and professional partners. This process also helped to expose the complexity of building a successful business, and the many areas of expertise involved.

3.3.3 Packaging and Point-of-Purchase display

In a retail environment, it is often the packaging of a product that consumers see first, and which communicates a great deal about the product to the consumer. Packaging sometimes costs more than the product itself. For these reasons, packaging became a primary focus in this project.

Students were required to develop a product name and logo/identity, create packaging for the 20 units with necessary graphics/instructions to inform consumers, and create a point-of-purchase display to showcase and communicate their product in the retail environment. Our intention was not to transform students into packaging design professionals, but to provide an experience to improve their branding and graphic communication skills, and to develop a greater understanding of how and when to coordinate graphics and packaging needs on future projects. Towards this, we collaborated with the Graphic Arts and Imaging Technology program on our campus, and utilized their packaging prototyping tools.

3.3.4 Create a retail event

As a group, students worked together to conceptualize the 'pop-up shop' where they would retail their products, developed a shared promotional campaign, created signage and other marketing collateral, and managed the retail event. Students were divided into three teams to plan the event: Marketing/Public Relations, Space Planning, and Signage/Graphics.

3.3.5 Outside Submissions

Students were required to submit their final design to an outside agency or venue. This could be a retailer, a design competition, a product development company, crowdsourcing site, etc. This requirement greatly changed the significance of the project (see outcomes below). Just like the self-defined nature of the project, students were asked to find their own opportunities where their product would have the most potential. Several students submitted their project to Quirky.com, a website that creates new products based on popular votes and crowdsourced design development. One student submitted his project to Edison Nation, a company that specializes in partnering inventors with manufacturers. Others students submitted directly to retailers and manufacturers.

3.3.6 Read and reflect

To support project development, and provide insight/inspiration along the way, several readings were assigned in conjunction with this project. These helped in areas of research, ideation, packaging, and graphic development:

- *The Adjacent Possible*, Ch.1 in **Where Good Ideas Come From**, by Steven Johnson, pp.25-42.
- **Shaping Things**, by Bruce Sterling, pp.6-24.
- *How to Make Almost Anything*, Ch.1 in **FAB: the coming revolution on your desktop – from personal computers to personal fabrication**, by Neil Gershenfeld, pp.3-27.
- *Understanding Target Markets*, from **Packaging Design** by Bill Stewart, pp.38-57.
- *Defining Package Design*, Ch.2 in **Packaging Design, Successful Product Branding from Concept to Shelf**, by Klimchuck & Krasovec, pp.33-51.

3.4 Project Outcomes

This project succeeded in providing students with experience in a broader spectrum of product design than they typically have in a product design studio class. By going beyond a studio sketch or prototype, and demanding that students produce a business plan and multiple identical products that were retail-ready, students experienced success on multiple fronts.

3.4.1 Professional Placement

Success from this project has been exhibited via student placements in jobs and internships related to this type of small-scale design entrepreneurship. One student is now an intern at Quirky in NY City. Another student continued with a similar project the next semester and is now working full time for Maxx&Unicorn, a boutique fashion accessories company in Brooklyn, NY. One student was a finalist on Quirky.com, and though her product was not selected, the press from Quirky led to a professional internship with ANDESIGN LAB in California. Another student who participated in an earlier version of this project, later launched his own crowdfunding project, and is now working for Kikkerland Design in NY.

3.4.2 Benefits from outside submissions

Because of the requirement to submit their finished work to an outside company, 3 of the 12 students had their products selected and further developed by an outside company. That is a 25% success rate in bringing products from this project to the larger market. One of these was selected by Quirky.com for further development towards mass production; another was picked up by a local manufacturer and the first 100 units were produced for market testing; and the third was self-produced with the support of a local retailer that agreed to carry the product in their store.

One of the greatest successes from this effort was when a student entered his business plan into a national ‘Business Pitch’ contest, the Retail Innovation Challenge at Wake Forest School of Business. In this contest, teams of students (usually graduate-level business students) pitch their business ideas to professionals to win seed capital. This student (from an undergraduate design program) won second place and was awarded $5,000 to develop his project further. This has encouraged other students to pursue business pitch competitions outside of this class, and has since led to three additional students winning cash prizes in such competitions over the past year.

3.4.3 Retail Results
A majority of students made a profit on their investment in the project through the retail event. In discussions with students after the sale, this was a highlight for them. They said that they are used to spending over $100 on models for a studio project, but then throwing them away after a project is completed. Making money got their attention and was very encouraging.

Working directly with potential customers also gave the students an entirely different perspective on their project. They are used to in-class critiques, or showing their work to other designers. However, having to pitch their product dozens of times to random strangers (a.k.a. potential buyers) was new, and helped them refine their 'pitch' and to better understand users' perspectives and needs.

In the first year of the Design Store event, 7 of 20 students sold out of their 20 product units, some taking additional orders at the event. At least five more sold out within the week from follow-up sales. The next year, 3 of 12 sold out of their product inventory during the one-day sale; 6 of 12 made a profit; and the average student generated $280 in revenue.

3.4.5 Student surveys
A project evaluation survey was given to students after completing the project. In this survey, students were asked about the educational and professional relevance of the project, and whether they viewed the project as being helpful in their careers. While it was a small sample size, the response was overwhelmingly positive. Many of the students said they felt prepared to help future clients bring products to market, now that they had experienced the process of branding, packaging, pricing and retail. Based on conversations early in the semester, this was a confidence they did not have previously. Most students also felt that they would be willing to do another self-production project in the future.

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KICKSTARTER'S ROLE IN INDUSTRIAL DESIGN EDUCATION

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ABSTRACT
This paper provides a basic explanation of the Kickstarter platform and reports on the findings from five interviews conducted with design students who openly shared what they have learned from their experiences with Kickstarter projects. It also summarizes a successful design student Kickstarter project, the Tessel Jet Pack Backpack.
The results of this research indicate that design students are primarily motivated to engage in Kickstarter projects to validate themselves as designers. Secondarily, students found these projects exposed them to new learning in marketing, finance, manufacturing, product delivery, and the complete "start to finish" framework of a product development process. Surprisingly, they also indicated that the experience only reinforced their pre-existing design training and did not significantly add to it.
Despite the student learning that occurs throughout a Kickstarter project, we do not recommend that Kickstarter supplement or supersede design education because of the inherent real-world consequences. However, professors should consider how intrinsically-motivated, self-determined projects that build young designers' self-esteem can be used to enhance current design studio courses.

Keywords: Industrial design, design education, self-efficacy, student motivation, designer validation

1 INTRODUCTION

As design educators, we have observed a growing trend in the number of students who choose to participate in entrepreneurship activities such as Kickstarter projects while enrolled in traditional university courses. Over the past four years, approximately 25% of the industrial design students at Brigham Young University have chosen to run their own Kickstarter project or participate in a Kickstarter class offered by the business school on campus. Design educators should understand the implications of this trend and how it may affect their students and their curriculum.

1.1 Kickstarter

Kickstarter, founded in 2009, is a web-based global crowdfunding platform that helps individuals fund creative projects [1]. This platform provides a vehicle for individuals to design, market, fund, manufacture, and ship a product they have designed. Kickstarter is part of a larger phenomenon known as crowdfunding, or the practice of micro-financing blended with the concept of crowdsourcing. Crowdfunding is a growing class of fundraising, facilitated through online sites that connect project founders to potential consumers [2]. An early and broad definition of crowdfunding is given by Lambert and Schwienbacker as "an open call, essentially through the Internet, for the provision of financial resources either in the form of donation or in exchange for some form of reward and/or voting rights in order to support initiative for specific purposes" [3].
Kickstarter uses a reward-based form of crowdfunding, wherein backers (funders) are offered a reward for supporting a project. These rewards are varied and usually are divided into levels of support, beginning quite low but with increasing rewards as incentive for increasing pledge amounts. Kickstarter follows an all-or-nothing model, which means if the project does not reach its funding goal, the backers are not charged for their pledge and the founder receives no money.

Kickstarter is a global entity based in Brooklyn, New York, U.S.A. At the time of writing, 741 projects have been successfully funded with a total of $1,534,643,187 pledged. 44% of projects have reached their funding goal. Of the 66% of unfunded projects, 12% run their course having received no pledges at all [4].

1.2 Student Motivations

We first became interested in the student motivation behind participating in Kickstarter in 2013 while observing a third-year student. He developed a personal project for Kickstarter, the Tessel Jet Pack Backpack, in addition to his industrial design schoolwork. We were both concerned and interested. On the one hand, Kickstarter projects are large, time-consuming, stressful efforts that take time away from coursework. What's more, Kickstarter is trendy—with the consistent stream of stories and excitement surrounding the projects, it is rare that a design student has not contemplated running their own Kickstarter campaign. On the other hand, we were interested in understanding the strong motivating factors compelling students to participate in large projects in addition to their coursework.

While other researchers have described ways to integrate Kickstarter and entrepreneurship into design education [5], [6], we sought to determine what drives this motivation and whether or not Kickstarter is beneficial to design programs. Our initial assumption was that Kickstarter is a powerful vehicle to assist students in their design education and should be utilized by educators.

Understanding student motivations will enable design educators to strategically manage their course structures to remain relevant to the evolving design student. It will also allow educators to create courses and assignments that are as compelling as a Kickstarter project, pushing students to create their best work.

2 METHOD

In 2014 and 2015, we conducted three informal interviews with the student who created the Tessel Jet Pack Backpack. We wanted to understand his project, what he had learned, and whether he thought his Kickstarter experience was beneficial to his design education. We also interviewed four other Brigham Young University students who participated in Kickstarter projects while enrolled in classes. The students interviewed participated in a total of seven projects; five were successfully funded and two were not. We interviewed one student three times for about an hour each time, and interviewed the other students for about fifteen minutes to one hour.

In these interviews, we asked the students the following questions and noted the responses:

1. Why did you want to participate in a Kickstarter project?
2. What did you learn from your Kickstarter project?
3. Why did you do a Kickstarter and attend classes at the same time?
4. Did your Kickstarter project help you to get a job or internship?
5. What was your motivation for participating in a Kickstarter project?

These questions all sought to draw out the foundational design education value of a Kickstarter project, both by asking explicitly and by asking about hypothesized motivations. The final question became the crux of the interview, and often required persistence and follow-up questions for students to fully answer, suggesting that students are not consciously aware of their own motivations. Findings from these interviews and a case study of the Tessel Jet Pack Backpack are presented in the following sections.

3 STUDENT MOTIVATIONS AND LEARNING

Through our student interviews, we determined that validation of the student's design abilities is the primary motivation for participation in Kickstarter. In addition, the students learned a variety of lessons related to design: working with team members, online communication, finance, manufacturing and distribution, and a "start-to-finish" business experience. We also found that Kickstarter projects allow students to polish their existing design skills but do not significantly aid them in acquiring new ones.

3.1 Validation

We determined that the primary student motivation to participate in a Kickstarter project is the validation of themselves as idea creators, product makers, and in general, respected designers. A successful Kickstarter project promotes a feeling of self-efficacy.

The psychologist Albert Bandura explains that the most persuasive mechanism to provide an individual meaning in their life is their judgment of efficacy [7]. Students referred to the confidence buzz they received when strangers from countries they've never heard of validated their work with a monetary commitment, indicating that their idea is of real worth—much more compelling than a "like" or a "favorite" in an online social setting. These strangers, responding to their project, provide a stream of highly valued reinforcement of their competencies as a producer and designer. The students expressed that such a response from a blind peer review is more validating than feedback from a professor who knows them personally. They become accountable to the real consumers of their product—success or failure is more important than a letter grade.

Motivation experts such as Deci and Ryan also support this notion. They would argue that self-determined events or behaviours that conduce *feelings of competence* enhances "intrinsic motivation for that action because they allow satisfaction of the basic psychological need for competence [8]." Importantly, they maintain that *feelings of competence* will *not* enhance intrinsic motivation unless they are accompanied by *a sense of autonomy*. In other words, "This project was my decision, and the consequences, positive or negative, are also my responsibility." Kickstarter projects are self-determined; intrinsically-motivated projects that conduce feelings of competence and consequently provide self-efficacy as young designers and businessmen and women.

3.2 Build Your Teams Wisely

A common topic that emerged in the research was the need for interpersonal skills involving co-campaigners or team members. Design students identified two types of students involved in product-oriented Kickstarter campaigns. One type are students motivated by the prospect of generating personal capital with the least amount of effort. They focus primarily on the monetary transaction and employing newly-acquired business knowledge in a dynamic, "real life" setting. These students are characterized by their interest in all things fiscal and only a mild interest in the quality or type of product. Business students typically fall in this category.

The other type of student is product-oriented, motivated by the possibility of seeing their concept become a realized product. This type of student is usually less skilled or interested in the operational aspects of the project, but focused on the quality of the product. Design students typically fall in this category.

In the students' experience, a high level of frustration occurred when members of a campaign were comprised of both transaction-focused students and product-focused students, especially where one type had little interest in the other's focus. On the other hand, a high level of passion and achievement was realized when business students respected and valued good product design and the design students embraced the financial and logistical aspects of the campaign.

3.3 Online Communication

Students also spoke about the difficulties and nuances of online communication. To be successful in a Kickstarter campaign, a large online audience needs to be reached. The majority of Kickstarter campaigns include a video that explains the product, the team, and why the effort matters. Students learned that a visually engaging video without a strong narrative does not necessarily lead to success, and vice versa. For example, one student engaged the services of a notable local videographer to produce the video for their new campaign. This was a follow-on campaign to their first highly successful campaign and they were full of confidence. However, this new campaign failed to be funded. Upon analysis, they concluded that although the video was well-made, it did not convey the product's narrative appropriately. They rapidly adjusted the video's narrative, focusing on the essence of the product itself and eliminating much of the creative asides found in the first video. They remade the video themselves in the back of a classroom and re-launched the product, which was then successfully funded. As studio classes typically emphasize, while the quality of the communication is important, the quality of the product's narrative is even more so, and is quickly rewarded or punished in a Kickstarter campaign.

Getting eyes to view a campaign is also difficult. Many students rely on family and friends to initially back their campaign to demonstrate an attraction to the project and begin the funding process. Since successful funding typically happens within a few days of launch, a project needs hundreds or thousands of early backers to be successful. This is beyond the scope of most personal networks. Consequently, students learn that they have to engage directly with online bloggers and product-oriented websites with large audiences to lead their viewers to the Kickstarter campaign. This requires the product to be useful, useable, and desirable, or the bloggers will not promote it. Additionally, the online elite easily dismiss photography, graphics, and product design and narrative if not professionally presented. The project must somehow be outstanding for bloggers to feel it worthy of forwarding to their audience.

3.4 Finance, Manufacturing and Distribution

Design students were surprised by the amount of attention required by the various aspects of running a business, topics which are not typically addressed in design education. A great product alone does not make a successful campaign. Working with real money, customers, vendors and governments is both stressful and time-consuming. Design students are typically not familiar with tracking money for travel, materials, taxes, fees, shipping, prototypes, development, visual communications, bloggers, rent, equipment and so on.

Many of the products are manufactured by the students themselves, while others engage full-time manufactures, typically overseas, to produce their products for them. In either scenario, the students quickly discover that making one to ten prototypes is very different from manufacturing hundreds or thousands of the same product. Previously-held notions of product quality and consistency, manufacturing time and material cost, as well as product storage and distribution, are rapidly adjusted to reflect reality.

When all the manufacturing issues are resolved and the product arrives, the students face the challenges of shipping. Space requirements for thousands of boxes, placing the correct address of each customer, and purchasing postage for each package take more time and money than anticipated. Again, this is not a topic that is typically covered in design studies, but is an essential part of running a business.

3.5 Start-to-Finish

During the interviews, the design students proudly referred to the broad learning that occurred while participating in a complete, start to finish business experience. The students listed a number of new topics or skills they were required to address to complete a campaign. Product design was listed first, but students also included graphic design, web design, packaging design, photography, distribution, customer service, quality assurance, legal issues, business strategy, pricing, business issues, accounting, taxes, marketing, advertising, social media, editing, retail connections, pitching to investors, material sourcing, expense management, and equipment maintenance. While these topics are all important aspects of business, the majority of topics listed are not the direct focus of industrial design studies.

Students expressed that Kickstarter helped them develop the design skills they had already acquired through university classes, but did not significantly add new skills. Kickstarter helps students polish low-level design skills without strongly contributing to higher-level critical thinking, which should be an aspect of design education.

4 CASE STUDY: TESSEL JET PACK KICKSTARTER PROJECT

The Jet Pack began as a student-initiated design project from a third year student. He began with a backpack concept that featured a tessellated panel that makes up the body of the pack. When loaded, these tessellations create a unique faceted effect on the surface that conveys the shape and volume of the pack's contents [Figure 1].

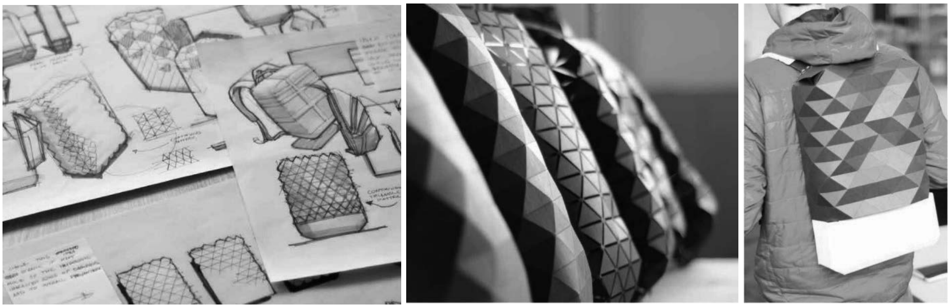

Figure 1. Sketches and early prototypes of the Tessel Jet Pack

He worked for months and generated many design iterations in paperboard, sheet foam, and fabric. During this time, he received informal critique and input from faculty and classmates. He was able to recruit two other students to his project, one a design studio classmate and the other an acquaintance studying business. Throughout this process, he divided his time between working on his assigned projects and this side venture.

As the project progressed, the small team gained access to an industrial grade sewing machine and developed prototypes of high enough quality to allow simple product and market testing. Despite having no training in product development and lacking any manufacturing process experience, the team began looking for possible manufacturers and preparing their project for a Kickstarter launch.

This preparation included creating an appearance of legitimacy. As three inexperienced students, they knew it was important to portray themselves as a reputable and reliable entity with a high quality product. They crafted manifestations of a developed brand through creating a website, orchestrating a sustained social media campaign, and developing a strong brand story. This narrative helped them establish and communicate product values through their pitch to prospective backers.

With these measures in place, the three students launched their Kickstarter campaign. After 33 days they had exceeded their goal of $17,000 by over 300% through garnering 846 backers reaching a pledge level of $56,045 [Figure 2]. However, at this point they had not yet received a finished sample from the manufacturer. Predictably, their pack proved more difficult to produce than they planned, especially the tessellated panels. Seven months and many factory samples later, they had a satisfactory production-ready prototype. During this development time, they learned the importance of open and transparent communication with backers and spent considerable time with customer service issues. The initial shipment of 1200 Jet Packs arrived from the factory in Asia almost one year after launching the project. The team then faced the issues of distributing their packs to all 50 US states and 20 countries.

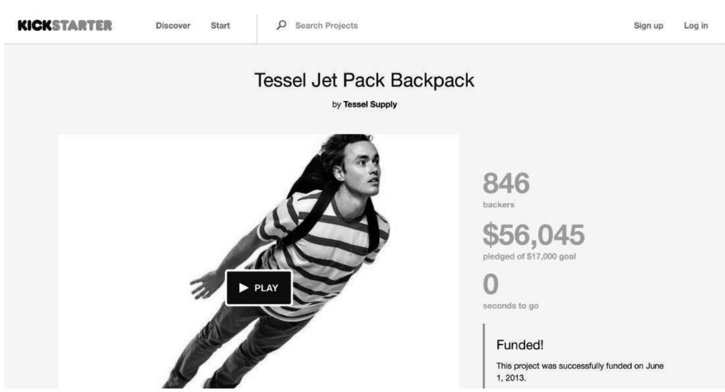

Figure 2. Kickstarter Funded! page of the Tessel Jet Pack

The student reported that the success of the Tessel Jet Pack verified and validated his skills as a designer. He made connections to other designers and businesspeople through this experience that he could not have made otherwise.

However, this project has also made it more difficult for this student to get an industrial design job with some soft goods manufacturers. Because of the success of the Tessel business, this student is often considered a competitor to a potential hiring company in a similar market. Additionally, his focus on soft goods lead him to neglect skills in other areas that traditional industrial designers have, such as CAD modelling.

5 KICKSTARTER'S IMPACT ON DESIGN EDUCATION

All of these things considered, is Kickstarter a friend or foe to industrial design education? Certainly, it can be a foe by taking away from time spent on class assignments and, in rare cases, by making it difficult for the student to get a job in their project's sector. However, it can be also be a friend by encouraging students to pursue projects that interest them and by giving them opportunities to polish design skills, learn business and communication skills, work in groups, and take on real-world responsibility and challenges.

The personal validation from a Kickstarter project is clearly potent enough to drive busy students to take on enormous amounts of high-risk responsibility. We originally hypothesized that the strong motivating factors of Kickstarter lend it as an ideal venue to further design education. However, because of the results of the student interviews, we have determined that Kickstarter is not a good tool for professors. One reason for this conclusion is that Kickstarter requires students to face real-world consequences in the success or failure of their product, which should not be part of education. Education is a safe place for students to make mistakes and gain a foundation before they enter the "real world" of design. While some students are ready to face these challenges while they are in school, this is not true in every case, and many students may not be comfortable with inherent difficulties and consequences. However, we recognize that receiving positive feedback from real consumers is a key aspect of the validation motivating the students.

If we can find ways to motivate our students in the classroom the same way these Kickstarter projects motivate our students, we can expect a higher level of commitment and persistence to projects. This will require exploring meaningful sources of validation beyond students' peers and professors such as design shows, portfolio-sharing websites such as Behance and Coroflot, or design reviews from industry professionals. These venues offer validation from outside sources without the inherent difficulties and consequences inherent in a Kickstarter project.

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ENHANCING COMUNICATION SKILLS THROUGH STUDENT AND ENTERPRISE INTERACTION

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ABSTRACT
Collaboration between a university and an industry is a common way to create "realistic" student projects that provide opportunities for gaining useful knowledge of "real-world problems," skill development, and project management. To use university-industry collaboration as a way of teaching communication is not new. However, most courses using this approach focus mainly on written and verbal communication. A case study of a second year bachelor's level product design course, which focused on project-based learning as a pedagogical platform, was used as the primary research method. This research aimed to conduct further inquiry into how external collaboration can contribute to more holistic communicative learning. The findings indicated that this approach leads students to a more holistic communicative understanding. Furthermore, using student-driven processes resulted in better communicative insight than teacher-driven processes. The processes did not necessarily lead to increased semantic awareness; however, the course created an arena where students could adjust their semantic perceptions. Both student- and teacher-driven processes created engaged students and the possibility to build individual strength in students through conquering fears and attaining the satisfaction of achievement. However, there were some cases of students not handling the pressure of delivery.

Keywords: Learning space, enterprise collaboration, communication, semiotics, project-based learning.

1 INTRODUCTION

Several researchers have claimed that product design cannot or should not be performed without the intention to communicate [1-3], and that design is about making sense of things. The Swedish designer and semantic researcher Rune Monö [1] said: *"Product design cannot exist without the intention to communicate."* To design for product understanding, the student must develop consciousness towards using communicative elements [1]. One way of creating communicative awareness in product design education is through projects, such as this one, which focused on increasing students' awareness towards the communicative complexity of design and communications potential to make understandable and desirable products. The assumption is that product design students working with external partners increase their awareness of communication as a tool. In this research, communication is viewed as a holistic communicative awareness regarding issues such as, product semantics, semiotics, written and oral communication and communication with consumers and industry, with focus on how this communication affects the design process.

2 BACKGROUND

The psychologist Gregory Bateson claims that one cannot not communicate [4]. According to Rune Monö [1], signs in artifacts are all elements that can be interpreted through our senses and that give meaning to an artefact. In other words, it is what we call product semantics. Semantics in design have been developed for half a century, but the term "product semantics" was first introduced by Butter and Krippendorff in the Industrial Designers Society of America's (IDSA) journal *Innovation* [5]. They define product semantics as both [6]:

- A systematic inquiry into how people attribute meanings to artifacts and interact with them accordingly.
- A vocabulary and methodology for designing artifacts in view of the meanings they could acquire for their users and the communities of their stakeholders.

It is communication in all the signs we use in the design of artifacts [1]. Due to this, communication should be viewed as an important and integral part of design. Areas of communication, such as aesthetics, semiotics, touch points, branding, and verbal communication, are often addressed through product development. Aesthetics is a useful communication tool that can lead to products being perceived as more functional [7]. Furthermore, semantic awareness is important for the designer to create understandable and emotional products [1, 3, 8, 9]. Krippendorff [3] emphasizes a semantic turn within product design. He demands that designers shift their attention from the design of material artifacts to the design of artifacts whose meanings enable desirable interfaces to arise. In this context, teaching holistic understanding of communication is important within design education. After graduation, most design students are inclined to work with industry. To prepare students for this, it is important that they gain field experience regarding design development and communication skills [10]. It can be challenging to achieve this within the learning space of a school.

2.1 Industrial collaboration

Most design schools implement industrial collaboration in their curriculum; this leads to students gaining useful knowledge in "real-world problems," skill development, and project management [11]. The National Academy of Engineering, the American Society of Civil Engineering, and other experts in the field of engineering education concur that so-called "soft-skills" are necessary for students to succeed professionally upon graduation [12]. However, this knowledge can encompass a variety of issues [13], and within design research, there has been little focus on enterprise collaboration as a tool for communicative learning. Some universities have courses which combine design, communication, and enterprise collaboration like the Engineering, Design, and Communication (EDC) course at Northwestern University [10]. This is a successful course that proves the usefulness of combining industrial collaboration with communicative learning. However, these courses seem to have their focus on written and verbal communication, while issues like product semantics are of lesser interest. To some degree, EDC [10] separates design and communication by viewing them as two disciplines taught within the same course. Several researchers [1, 3] have viewed this in a more holistic way, seeing communication and design as one thing. Krippendorff claims, *"design is making sense of things"* [14], and says this phrase can be read as *"design is a sense creating activity,"* or it could mean, *"the products of design are to be understandable to their users."* Viewing design and communication in this holistic perspective indicates that it can be useful to view collaboration with external partners and communicative learning in a wider sense.

2.2 Project-based learning

Lantada et al. [13] described project-based learning (PBL)—together with funded final degree projects—as the most valued strategy for linking a university with the "real" industrial world. PBL is a model that organizes learning around projects. PBL has similarities to problem-based learning [15]. Within the research on PBL, there is diversity in defining features coupled with a lack of a universally accepted model or theory of PBL, which has resulted in a great variety of PBL research and development activities [16]. To sort this out and answer what a project must have in order to be considered an instance of PBL, J. W. Thomas [16] established five criteria:

- PBL projects are central, not peripheral to the curriculum.
- PBL projects are focused on questions or problems that "drive" students to encounter (and struggle with) the central concepts and principles of a discipline.
- Projects involve students in a constructive investigation.
- Projects are student-driven to some significant degree.
- Projects are realistic, not school-like.

2.3 Research question

When working with external partners, students increase their learning spaces, both physically and mentally. Physically, this can include field trips or external meetings. Mentally, it can be about challenging their comfort zone and forcing them to place their design in a context. To investigate how students can learn communication skills through out-of-school experiences, the following research question was asked: How can design students enhance their communication skills by working with external partners?

3 RESEARCH METHODS

The primary method used in this research is a case study [17] of a 10 ECTS[1] second-year, bachelor-level course named "Communication & Presentation." Different approaches were practiced over a six-year period, and an average of 40 students each year collaborated with external partners using teacher-driven or student-driven processes. The research question was analyzed through participatory observation in class, archival studies of students project reports [17], course evaluations, and reflections. The process used in this course can be described as project-based learning [11, 16]. This method was used as a pedagogical tool to increase learning in the process and to achieve communicative insight.

3.1 Teacher-driven process

Initially, the course ran as a teacher-driven process. The course leader established collaboration with four to five enterprises, and students signed up for the collaboration in which they wanted to participate. Students worked independently or in groups of two or three, resulting in several students or student groups working on similar tasks. This way of organizing focused on the course leader arranging meetings and following up the collaboration with the enterprise.

3.2 Student-driven process

After two years of running teacher-driven processes, students got the opportunity to choose between established collaborations or arranging independent enterprise collaborations. This offered an opportunity for student-driven processes; students located their own partners and arranged the collaboration work, meetings, and follow-up. This was the main approach during the final two years of the study. It was essential for both teacher- and student-driven processes for the student to establish their own problem definition or research question. This criterion is a subtle one in PBL projects [16].

4 RESULTS

The findings of the study showed that students increased their communicative insights through experiencing challenges first-hand. Student-driven processes expanded the communicative learning to a larger extent than teacher-driven processes. In addition, the communication process affected the design development. The process did not necessarily lead to increased semantic awareness, but it created an arena were students could adjust their semantic perceptions. Working with external partners provided students the opportunity to build individual strength through conquering fears and attaining the satisfaction of achievement. However, there were some cases of students not handling the pressure of delivery.

5 DISCUSSION

5.1 Collaboration work through project-based learning

It seems that most design schools run teacher-driven processes in their organized collaboration work [13], although there are many exceptions, especially on final bachelor exams and at the master's level. A teacher-driven process takes fewer risks because it gives the teachers control. When students collaborate with an industry, they function as representatives of their schools. Not controlling this process can, in the worst case, give the school a bad reputation; it is risky to allow second-year bachelor students to run their own collaboration projects. There are many pitfalls regarding themes such as project organization, communication, and intellectual property rights. However, addressing these issues using project-based learning can create a prosperous learning experience [11]. To ensure good projects and satisfied industrial partners, it is important to follow up on the projects. In this case, it was done through tutoring and milestone meetings where students shared their experiences and not only discussed but also received advice on further communication with their partners and the development of their design. In addition, they attended lectures and workshops on communication to prepare them for the task. Previous projects had given them experience through teacher-driven collaboration work. We emphasized the importance of presenting collaboration partners with realistic goals for the project; if the gap between what the company wants and what they get is large, the students will not be good ambassadors of the school.

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[1] The European Credit Transfer and Accumulation System

"To work with a real external partner has been fulfilling. These tasks are very useful regarding preparing oneself for the real working life as a designer." This statement from a student's reflection exemplifies that students felt external collaboration work through student-driven processes was relevant to their future occupation. Furthermore, it shows that they enjoyed this approach to learning. Another student expressed something similar: *"I feel I learned to take a very realistic approach to my design, highlighting how I would hope to work in the future as opposed to undergoing the process like any other school project."* Both of these examples illustrate a strong expression from most students. They enjoyed struggling with "real-world" problems and felt they learned a lot from the process, specifically mentioning the connection this learning had with their future work as designers.

For a project to be a PBL, it must be realistic and not school-like in nature [16]. Realism is more present in student-driven than teacher-driven processes. When teachers arrange meetings and fieldtrips with several students participating, it creates a more school-like setting. Another criterion for PBL is that it is student-driven to a significant degree. One can argue that the student is the main driver in teacher-driven processes. However, it seems that the student has a stronger position as the driver for student-driven projects. In most cases, a teacher-driven process is not a PBL project due to its more school-like position and the weaker student-driven approach. Teacher-driven projects fit better into the category of problem-based learning [15]. According to Lantada et al. [13], PBL is the best approach to industry-university collaboration work. This view corresponds with the findings of this study.

5.2 Semantic and aesthetic insight

Running student-driven processes where they worked with external partners did not necessarily lead to increased aesthetic and semantic awareness, and student insight regarding this varied. For this to occur, focus on the issue through tutoring and lectures was usually necessary. Nevertheless, the process, including tutoring and milestone meetings, created an arena were students could adjust their aesthetic and semantic perceptions. Most students showed increased insight into the field of semantics. One student said: *"I have actually caught myself, sitting on the bus, thinking about how traffic signs are a good example of semantic signs."* The relationship between signs and product understanding could also be found in several projects, exemplified by this student statement: *"Several aspects regarding the product feel more controlled now than before. This is the most important lessons I have learned in this subject."* This is an important insight that corresponds with Monö's ideas, as he emphasized that design semantics shall lead to artifacts expressing their intended characteristics in a comprehensible way, both regarding use and identity [1]. This is further exemplified through a student who expressed increased knowledge of hidden meanings and agendas behind products. *"To analyze and decipher elements, messages, and underlying goals behind products is contributing to consciousness regarding both being a designer and a consumer."*

5.3 External collaboration – a tool for communicative learning

Working with external partners creates engaged students. Students wish to perform well when a third party is expecting excellent results and efficient delivery. One student expressed, "*I had a greater drive to achieve not just quantity, but quality in the design to provide a worthwhile experience for not just myself, but for the company, who took the time to involve themselves in this process."* Many see this kind of project as an opportunity to establish contacts and build a portfolio as a way to increase employability [12, 13]. A statement from two collaborating students' project report supports this view: "*For us, an important aspect throughout the project has been to develop a concept that could be realized."* However, it can be scary to challenge one's comfort zone when they seek collaboration in the "real world." Several students confirmed this. One stated: *"It was scary to ask one of Norway's largest furniture manufacturers, but I am glad we dared because during this course, we have learned a lot from the collaboration."* For most students, this is a positive force, which engages them to focus and perform well. However, some students aim too low or too high. Aiming too low can result in meaningless design tasks with little interest for both the collaborating partner and the student. This occurred with two students who were designing a shelf for a company. Ultimately, their partner only wanted a small shelf in his office, and he had already decided he wanted it to look similar to a shelf available at IKEA. Therefore, he obviously wanted carpenters, not designers. Their tutor advised them to change to a different collaboration partner, but they lost a lot of time in the process. Conversely, some students aimed too high, taking on complicated tasks that resulted in insufficient designs, followed by depression and sick leave. To make collaboration an effective tool for communicative learning, students must challenge themselves on the correct level. Most aim high without aiming too high and succeed. More importantly, these challenges create learning that would not have occurred in a teacher-driven process. Through struggling with communication with their partners, meeting arrangements, and misinterpretations, the students can derive knowledge for future encounters and projects. Thomas [16] emphasizes that the central activities of the project must represent difficulty to the student to be a PBL project. The project is an exercise if it can be carried out with the application of already-learned information or skills. Working with an external partner increased the pressure on the student, and in most cases, increased pressure motivated and enhanced learning.

5.4 Learning communication through student-driven processes

Working with an external partner can be a useful tool for development of enhanced communicative skills. Students used communication as a tool for product development in their process. An example is a project run by two students who worked on a chair for a large furniture company. To gather customer feedback on chairs, they conducted a workshop (Figure 1). The workshop took place in the furniture shop, and customers were encouraged to participate. The workshop generated important information regarding the customers' wants and needs concerning chairs. The feedback provided insights that affected the result on an aesthetic and product/ semantics level. In addition, it was a useful tool for gaining insight into communication strategies, illustrated through this statement from one of the participating students: *"The workshop made me conscious concerning how different ways to present a problem definition to the customers gave different information."* These students clearly used communication as a tool for product development.

Figure 1. Student-driven workshop at a large furniture shop

In another interesting example, two students worked with a local elementary school. The municipality decided in 2012 that this school would be a profile school in the subjects of mathematics, science, and technology. This knowledge became the inspiration for further work for the students. They used interviews and workshops with teachers and pupils to develop commission work for the school. To aid the process with their partners, they derived the words inclusive, curiosity, and innovation from the interpretation of their research. In addition, they made symbols for these words to use as communicative tools. This close communication led to solutions that would not have occurred in solitude. Additionally, their participation in the process created ownership for both pupils and teachers. The result focused on curiosity, learning, and the school's profile; the solutions became identity builders, pedagogical tools, and decorative elements.

Both examples illustrate ways of using communication as a tool for product development. All of the student-driven projects used communication as a tool. This did not appear to the same degree in teacher-driven processes. This shows that, at least in this study, the student-driven process is a better tool for communicative learning than the teacher-driven process.

6 CONCLUSION

This paper discusses a way to teach students communication skills through enterprise interaction. The research clearly indicates that to run a project as a student-driven process, rather than a teacher-driven process, contributes to a more holistic communicative learning. This study ran student-driven processes within the criteria of project-based learning [16]. The method constructed a learning arena in which students challenged themselves and received both in-house and external dialog.

Most students showed aesthetic awareness and increased insight into the field of semantics. However, the student-external partner process did not necessarily lead to increased aesthetic or semantic awareness. It was usually necessary to focus on these issues through tutoring and lectures for this to occur. Nevertheless, the process, including tutoring and milestone meetings, created an arena where students could adjust their aesthetic and semantic perceptions.

Even though several of the projects resulted in objects or solutions that the collaboration partners used, the majority of the projects did not result in production/realization. In some cases, the exercise was more beneficial for the students than for the enterprise. It could potentially have a negative effect on the reputation of the school and the companies' impressions of designers if the industry meets students that are not sufficiently skilled to handle the task. This is something to consider when conducting collaboration with external partners. In contrast, the method can lead to design students developing increased communication skills regarding enterprise collaboration, which again can lead to the enhancement of future encounters with the industry. Further research is needed to clarify this issue. From a learning perspective, this method enabled students to challenge themselves, feasibly reach higher independence, and increase their communication skills.

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THE SHARING ECONOMY AND DESIGN

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ABSTRACT
The sharing economy is gaining momentum and changing the way people think about and interact with products. The commercial economy has created a culture of conspicuous consumption, where status is displayed by owning lots of stuff. But the sharing economy encourages collaborative consumption where status comes from having access to a lot of goods [1]. In the sharing economy, companies use technology to facilitate peer-to-peer rental schemes [2]. These "using rather than owning" strategies have the potential to reduce our demand for natural resources, and revive the old virtue of building products that last [3]. For this reason it is important that design students be exposed to courses, lectures, and projects where they learn to design for the unique challenges of the sharing economy.

Keywords: Sharing economy, design, collaborative consumption.

1 INTRODUCTION

In the past ten years technology has dramatically changed our lives. The Internet, mobile technology and social media have revolutionized the way we connect and communicate with each other. They have enabled collaboration in ways that weren't possible, before now. Soon new technologies will enhance our products and revolutionize the way we interact with them. The sharing economy represents a movement in business to facilitate and monetize collaborative consumption using technology. It is growing quickly and soon designers will be asked to design products specifically for the sharing economy. They can do this by designing products with good shareability. Designing for good shareability happens in two stages: The first is to identify products with the proper attributes for collaborative consumption; the second is to design features for the unique challenges of the sharing economy. The proper attributes for collaborative consumption can be seen in successful shared products, they are: non-consumable, transferable, and underused. The unique challenges of the sharing economy occur in three main areas: Security, Maintenance, and Convenience. Design students should be made aware of both the attributes and the challenges of the sharing economy so they can design products for this new market.

2 THE SHARING ECONOMY

The sharing economy represents a fundamental shift in how consumers value products. In the current commercial economy, consumers value ownership. This causes a lot of conspicuous consumption. As a result many products are underutilized and wasted which contributes to our high demand for natural resources. Collaborative consumption can mitigate these negative effects, but poor communication and small social networks have traditionally limited it. Developments in technology over the past 20 years have overcome these barriers. New companies use the Internet, social media, and mobile technologies to create large networks of people who can easily participate in collaborative consumption. Forbes estimates that in 2014 the revenue generated by companies in the sharing economy "surpass[ed] $3.5 billion…with growth exceeding 25%" over the previous year [4].

2.1 Collaborative Consumption: Definition and Benefits

Collaborative consumption is a family of transactions that occur outside of the commercial economy. The family consists of six different types of transactions: borrowing/lending, gifting, renting, Bartering, Sharing, and Swapping, Figure 1. The most influential transaction type for the current sharing economy is Renting. Companies have embraced renting primarily because it involves a monetary transaction. The success of these companies represents a change in the way many consumers view products. Traditionally, products have been viewed as assets, but in the in the sharing economy they are viewed as services.

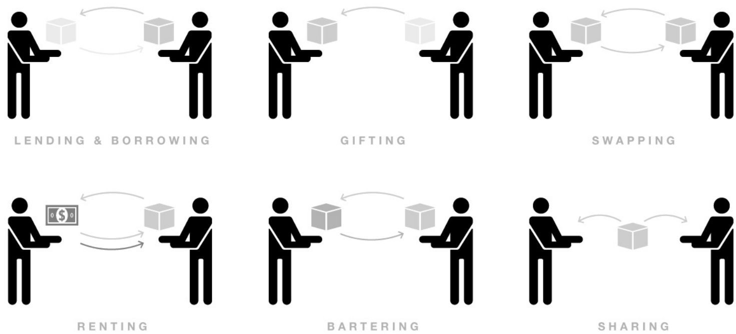

Figure 1. Diagram of the different types of transactions in collaborative consumption

Collaborative consumption can mitigate the negative effects of conspicuous consumption. Underutilization is a big problem. For example, the average American spends 18% of his/her income on a car that is stationary the majority of the time [1]. Collaborative consumption can maximize the utility of each product and minimize the cost to each individual, by distributing the product to those who need it, when they need it. The current economy also creates many disposable goods that could be replaced by fewer high quality products. This creates a lot of unnecessary waste. Collaborative consumption could in theory prevent this waste by providing access to quality products at a low cost. In short, effective collaborative consumption would significantly reduce the demand for natural resources that could lead to a sustainable consumption culture [3].

For example, Airbnb does a great job of facilitating collaborative consumption. They provide an online service where home and apartment owners can rent out rooms that are not being used. Overall, there is greater utility of existing housing, and fewer hotels need to be built and maintained. This saves building materials, energy, and time. It is also frequently less expensive for the consumer, when compared to hotel pricing.

2.2 Advances in Technology: The Internet, Social Media, and Mobile Technology

Collaborative consumption has occurred throughout human history but its scale has always been limited by geography and the size of social networks. The Internet has made peer-to-peer interactions possible at a speed, and on a scale that has never been possible before. Social media has expanded individuals' networks and personalized peer-to-peer interactions. Finally, mobile technology connected us to the network at all times, and introduced new tools, like GPS, that created more possibilities for collaboration. These three developments in technology have overcome some the difficulties of collaborative consumption. Continued improvements in infrastructure, and new technologies will make participating in collaborative consumption even easier.

Uber is perhaps the most talked about company in the current sharing economy. It is a software application that allows people to use their cars to provide taxi service. Uber uses many different technologies from GPS on both the driver's and the individual's phone, to electronic payments. None of it would have been possible before this technology became commonplace.

3 DESIGNING FOR THE SHARING ECONOMY

The sharing economy is growing quickly and designers should know how to design products specifically for it. They can do this by designing for shareability. Shareability is a collection of attributes that effects the success of a product in the sharing economy. When designing for good shareability, there are two stages: The first stage is to design products with the proper attributes for collaborative consumption; the second step is to design for the unique challenges of the sharing economy.

3.1 Attributes: Non-Consumable, Transferable, Underused

Bikes, cars, clothes, and power tools are examples of products with good shareability. They exhibit three attributes in common: they are non-consumable, transferable, and underused. Currently, renting is the most important transaction for the sharing economy and in order for a product to be rented it cannot be consumable. A product that is being used to its full potential has no need to be shared. And any product that is non-transferable cannot take part in collaboration, so it is excluded from the sharing economy. An example of this might be a prosthetic limb. Its custom fit makes it almost useless to anyone but the owner. Some product without these attributes may take part in collaborative consumption, but products with these attributes will be more successful in the sharing economy.

3.2 Product Challenges of the Sharing economy

The experience of renting a product can be full of troublesome moments. Most of these moments are caused by problems in three categories: security, maintenance, and convenience. These categories signify areas where innovation could improve the renting experience. Traditionally security has meant retaining ownership of your property, but security of a rented product is more concerned with ensuring the responsible use of the product. Owners will want products that will function for a long time to enable greater earning potential. They will look to purchase products with durable design and streamlined maintenance. Finally, designers should consider the challenge of storing and transporting the products. Solutions will vary depending on the specific product, but each category should be carefully considered for good shareability.

3.2.1 Security

Security will be a huge challenge in the sharing economy. As products travel between individuals it will be important to identify each product and track it. People undoubtedly will try to take unfair advantage of the services provided by the sharing economy, but features built into a product can allow for greater security. These include but are not limited to: GPS tracking, RFID tags that allow for identification, and usage tracking that confirms the product was not abused. All of the risks cannot be solved through physical features, but digital features, like peer reviews and ratings, can induce people to act responsibly.

3.2.2 Maintenance

A shareable product needs to be durable to withstand an increased usage in the sharing economy [1]. For many products this may only require higher quality materials, but some may require a more extensive redesign. The wear from increased usage also means that the product will require maintenance more frequently. To make this easy for the users, products should be designed with easy access to parts that will need maintenance or that are likely to break. In coming years 3D printing could also make the replacement of broken parts easy. It is also important to consider how a product will be cleaned. With so many people using a single product, hygiene will be an issue. Designs should avoid gaps, seams, and corners where build-up could occur.

3.2.3 Convenience

A challenging aspect of the sharing economy is the transportation of products, and the diverse group of users. Weight, mobility, and adjustability are important factors in making the product convenient. Heavy products can be extremely difficult for certain users, especially the elderly. Reducing the weight can help them and make transportation easier. Adding a handle may be enough to make smaller products mobile, but medium and large products may need wheels or be sized to fit inside the trunk of a car. Finally, making aspects of a product adjustable may be necessary to accommodate users of different sizes.

4 CONCLUSION

The sharing economy is growing quickly. Technologies like the Internet, social media, and mobile technology have made taking part in collaborative consumption easy. Consumers' preference is shifting to a "using rather than owning" mentality where products are viewed like services instead of assets. Soon companies will start asking designers to design products specifically for the sharing economy. The designers who can design for good shareability will be able to design products with the proper attributes and anticipate the unique challenges of the sharing economy. Many design students are already aware of the sharing economy but design professors need to help students recognize the attributes of successfully shared products and anticipate the unique challenges new products will face.

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Chapter 18

Design Methods

THE IDEALITY "WHAT" MODEL FOR PRODUCT DESIGN

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ABSTRACT
This article presents an innovative design model for both designers and engineers that can serve as a crucial compass during the formulation of a Product Design brief. The model was developed in order to bridge the gap that exists between the quest for sustainable design and the limitations of traditional briefs by focusing on the analysis level of the "WHAT" in order to enhance the "HOW" hands-on output. The model is based on the TRIZ ideality concept and the Bio-mimicry approach, incorporating sustainability principles inspired by nature. This design model directs designers and engineers through complex planning challenges, including the demand for sustainable processes and materials, novel attributes, efficiency, functionality and lower costs. Mechanical engineers and product designers that utilize this model achieve interactive strategic thinking that can balance the main planning stages of product functionality, such as manufacturing, advanced materials, logistics processes, marketing demands and related costs. This article presents and expands upon the theoretical basis of the model and also discusses its practical contribution through a case study conducted in an academic classroom experiment with students in a program for Mechanical Engineering and Product Design.

Keywords: Increasing benefits, efficiency, sustainability, TRIZ, Bio-mimicry, Bio-inspiration, ideality, product design.

1 INTRODUCTION

In light of global change it has become increasingly important that designers and engineers consider any influence a project may have on the environment, even in the earliest design stages [1]. At the same time, we are witness to fast-paced changes in the complexity of our modern way of life, both environmentally and socio-economically. The result is a pressing need for new models that will address the sustainability perspective in a complex environment, while improving the risk-management policies and design efficiency. While it is imperative that designers keep track of the current path of changing demands as well as international standards and technology costs, design methods have remained relatively conservative. As a result, some designs are too complex for the solutions that can be provided using traditional methods, which do not fulfill their needs [2]. Therefore, the idea that the designer must continue to provide solutions to new demands using these traditional methods is no longer relevant [3]. In light of this gap, designers must have the ability to glean skills from different fields and decide upon the best method for advancing the design process [4].

Nature is a promising source of knowledge that should be investigated for inspiration for innovation and sustainability in design. Biological systems operate within restricted conditions while minimizing waste and irreversible damage to the ecosystem. On the contrary, they often enrich and sustain ecosystems. Nature's forms and structures provide a wide range of properties while minimizing the usage of materials and energy. Nature-based manufacturing processes are conducted within the conditions that allow for life and therefore exist without high temperatures, strong pressures or toxic materials [5]. Natural systems demonstrate efficient energy and material flows. Therefore, design models that rely on nature-based solutions suggest promising potential for innovation and sustainability and allow designers to address sustainability during the early design phase [6]. These models are associated with the field of Bio-mimicry and Bio-inspiration—the imitation of nature

design solutions on the levels of structures, processes, systems, planning principles, strategies and patterns.
Bio-inspired sustainability design tools are based on patterns that are essentially simplifications of nature's sustainability design solutions. Life Principles [5] are strategies that nature maintains in order to survive under the conditions on planet Earth. The Ideality Tool for sustainable design [7] is another example of nature's sustainability patterns formulated by the TRIZ ideality framework. Ideality is a basic concept in TRIZ (the theory of inventive problem solving)[8], which describes the qualitative ratio of all system useful to harmful functions, or simply the ratio of system's benefits to costs, the two main ideality categories. The ideality tool for sustainable design utilizes nature's strategies to increase system benefits (e.g. multifunctional design) and reduce system costs (e.g. defensive strategy to prevent damage to the system). The relationship between sustainability and ideality was the basis for the development of practical eco-guidelines for product innovation and sustainability, while nature ideality strategies can serve as sustainability tools [7]. However, these bio-inspired sustainability tools do not incorporate product design methodologies in general or design brief methodologies and their specific requirements in particular. Adaptation of such tools for product design is therefore essential.
Product designers work mostly on multidisciplinary teams characterized by an amalgam of different approaches. While scientists tend to focus on how to solve problems through analysis, designers focus on user scenario and problem solving through creation [9]. Moreover, the challenges that arise when working on multidisciplinary teams are also related to environment complexity. The problems the designer must solve in a complex environment are considered to be "ill-defined" or "ill-structured"—that is, they are not clearly defined and cannot be solved using standard calculations [2]. As a result, there is a tendency to "skip" the "WHAT" stage and moved to the "HOW". The "WHAT" stage is crucial; if we formulate the details of the "WHAT" it will help us plan the "HOW" and select the type of solution we should implement. Thus, defining the "HOW" at the start of the brief will likely narrow down the designer's possibilities for finding additional solutions while adaptation of the bio-inspired sustainability tools for the needs of product design should address these multidisciplinary and complex aspects. The ideality model for product brief composition is suggested as a Bio- inspired sustainability tool, adjusted for a product design brief. The model aims to achieve a broader effect within existing constraints, launching the designer's capabilities in creating an ideal brief that focuses mainly on the question of the intention of the "WHAT" while avoiding the tendency to "flee" towards the question of "HOW".

2 THE IDEALITY "WHAT" MODEL FOR PRODUCT BRIEF

The ideality "WHAT" model for a product brief is based on the ideality tool for sustainable design [7] and serves as a design tool for the formulation of a design brief. The objective of the model is to achieve a broader effect within existing constraints, serving as a design platform for the schematic thought process of engineers in combination with the creative thought process of product designers. The structure of the model provides a useful starting point after receiving the client's brief. This contains instructions that must be followed while considering the existing constraints. The model promotes management, identification, definition and expansion of the opportunities that are embodied in the product and has an amorphic structure that changes and adapts to the product's needs. The model can be used by individuals or by teams. The model integrates creative and rational methods: first, it is based on the **creative method,** which focuses on Synectics as a technique for problem solving through creative thinking and varied analogies. The ideality "WHAT" model promotes the thinking process and steers it towards finding defined attributes using structured questions. Second, it is based on the **rational method**, which examines the various questions and adapts them to the list of actions required for ideal performance, all within the framework of the constraints and criteria. This allows for more targeted data flow and improved process efficiency and quality in the design decision-making process.
The use of a question format in the screening process helps to define the features of the functions crucial to the design and optimize the brief composition. The model is used as a checklist divided into topics and sub-topics that direct the designer inwards, emphasizing the various user scenarios and product usability. The complexity of modern products requires that the design focus on the user and his or her needs [2], an approach that allows for in-depth and intensive examination of the user's environment and schematic management of the design measures. Thus, the method requires both flexibility to account for crucial objectives listed in the brief and consideration of important

environmental and social issues. The design planning process must account for all of the environmental and ecological variables during all stages of product development [4]. It is the designer's responsibility to understand any problems and find solutions according to the defined product brief, while still accounting for the life cycle, profitability, and social and environmental aspects while minimizing resource consumption and waste production [10].

2.1 Model usage and its advantages

The ideality "WHAT" model is described in Fig.1 and contains two main realms of knowledge. The first aims to reduce costs and the second aims to increase benefits. Both categories have two layers (marked 2-3): The General Strategy and the Design Principle that form the basis the design brief. These two categories act as the foundations for the development of a "WHAT" oriented product design brief, and its two main sub-categories: Product Brief Checklist and Scenario-focused Questions (4-6). The product brief checklist deals with elements such as project management, regulation, production, marketing, user experience, prototyping, product features and their sub-categories. For example, the sub-categories of product's features and hard attributes, as presented in Fig.2, are engineering development, mechanical and geometrical properties, restrictions, features and performance. The intersection of these two realms of knowledge encourages designers to examine how each ideality principle can be realized in every product design brief and refers to the "WHAT" which leads to the "HOW" [8].

The following algorithm explains implementation of the "WHAT" model in the product design brief. First a central ideality category is selected with the objective of either increasing benefits or reducing costs, and then one of the ideality strategies and its related design principle is selected. Next, we address the product design space and choose a category from the product brief checklist and its related sub-categories. At this stage, as described in Fig 2, we examine how each one of the product brief sub-categories can be infused using the chosen ideality principle. For example, one could ask how to increase the number of functions associated with the product's mechanical and geometrical properties in order to increase the product ideality. We repeat this process for various ideality principles and design brief categories and associated sub-categories, though only in some combinations the ideality principles are applicable and shift the product design towards ideality, while in other combinations they do not. During the final stage, we examine the product brief categories and sub-categories in the framework of scenario-oriented questions such as "what", "which", "why", "where" and "when" (5), where the objective is to reach the most extensive range of possibilities in the search results. The product of this algorithm is a draft of the "WHAT" (6) qualities that will later dictate the "HOW" (8). At this point, through the integration of the Bio-mimicry approach, we can define design concepts for achieving the "HOW" through the use of inspiration, imitation and abstraction of solutions that are analogous to biological systems (7).

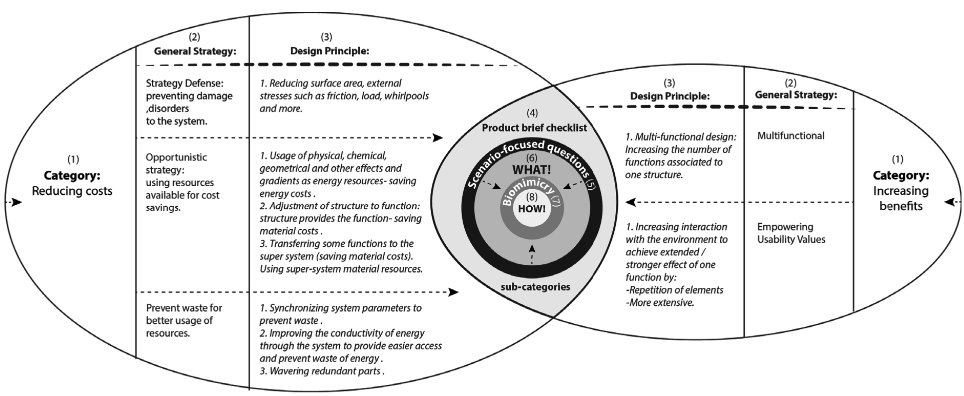

Figure 1. A schematic diagram of the model - the table provides a glimpse into the model

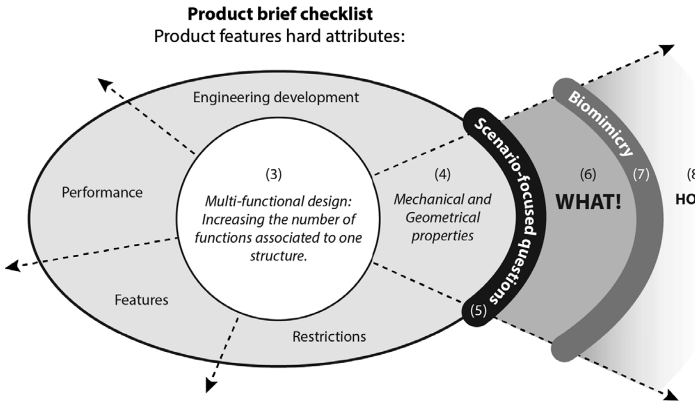

Figure 2. A schematic diagram of the model - the table demonstrates the view from inside the model out

2.2 How was the model developed?

The model was developed as a derivative of the sustainability ideality tool [7] in an effort to adapt it to the field of product design. The sustainability ideality tool [7] was modified to fit the terminology associated with design brief composition. A trial run was performed with implementation of the model in a classroom. After understanding and processing its weaknesses and features and examining what, if any, changes would be necessary, the model was updated forming the ideality "WHAT" model for product design. Finally, the model was presented in a diagram (Figure 1) to clarify its use.

2.3 Test case description – demonstration of the model

The ideality "WHAT" model for product design was tested with students in the third year of their B.Sc. in a program for Mechanical Engineering in Product Design. This program integrates mechanical engineering and product design combining project-oriented courses from both the faculties of Engineering and Design. Students benefit from synergic processes through critical and creative thinking. In this project-oriented course, we implemented the full methodical process of New Product Development (NPD). Each project begins with the composition of a self-brief and research of the "WHAT", followed by the "HOW". The engineering-oriented components integrate examination of alternative mechanical solutions and calculations followed by implementation and work with hands-on prototypes. The ideality "WHAT" model was presented in full and students were asked to use it when addressing a design challenge.

Design challenge background: Parents in Western cultures who wish to teach their children to ride a bicycle are exposed to a variety of bicycles, each designed for a different developmental stage. As a result, parents find themselves purchasing numerous bicycles, which both costs them money and takes up space. An ideal solution to this problem is a single bicycle that can be used for a long period of time and be easily modified according to the child's needs at each stage. Ideal device features include: ease of use, storage, weight and mobility. The design task was defined as the development of a multi-stage design concept for a children's bicycle.

2.4 Results

The students used the ideality "WHAT" model for product design, focusing on a variety of user scenarios. During the creation of the design brief, the model served as a thought framework, forcing the students to consider wide range of product aspects, aiming to discover the potential characteristics for future functionalities of the bicycle. Their focus on the **"WHAT"** created a crucial difference in their thought process, when it prevented them from dealing first with the **"HOW"** of the solution. The discussion developed and brought up the option of innovative product qualities; for example, as seen in Figure 3, a suggestion was made that injuries could be prevented and in the main ideality category of reducing costs, the concept of a "gyroscope precession" system was suggested as a method for injury prevention through improvement of balance and stability and as an alternative to training wheels. Additional features that arose and that are not described in figure 3 include: a feature for

avoiding emotional harm (frustration), physical harm (injuries), shortening the learning time for balance skills using bicycle feedback regarding the cycling performance. The method uses a (vocal) self-feedback system that covers both the emotional and physical aspects by providing the cyclist with information about stability, balance and integration with the environment (to prevent bicycle accidents). The same qualities mentioned above can also be associated with the challenge of stopping and starting pedaling. This feature, which identifies the ideal location for the pedals according to the rider's needs, is likely to be particularly effective for younger children
By implementing the ideality "WHAT" model for product design, the students developed and expanded upon ideas and product qualities that would likely not have arisen without the use of the model. Some of the more common qualities that had been previously identified by traditional brief composition methods were expanded and re-defined using the "WHAT" model. For example: conservation of energy in the system through the use of heat energy, etc. The model promoted innovation and helped the students reach new areas of thinking beyond the regular anchored thought processes. In addition, the model strengthened and promoted sustainable models for evaluating the use of the life cycle of the product, using multiple functionality and preventing damage to the system.

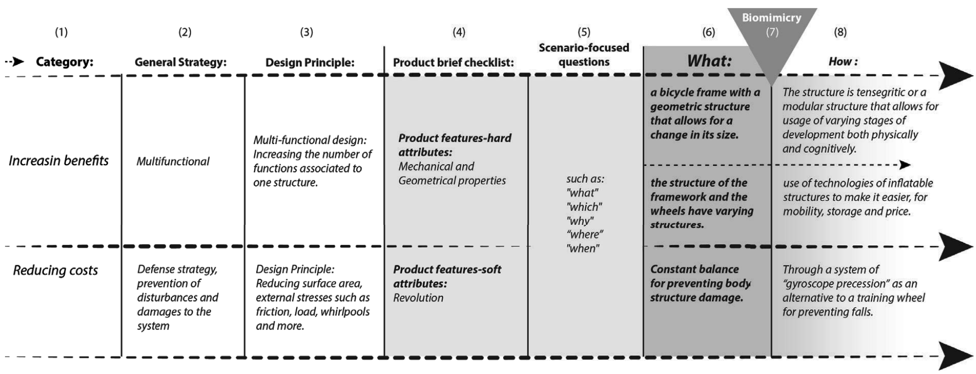

Figure 3. A Part of the case Study Diagram

2.5 Discussion

The "WHAT" model provides a path for following today's changing demands, complex environment and varying sustainability needs. Firstly, it addresses one of the major obstacles of the brief composition process and the tendency to focus more on the "HOW" and less on the "WHAT**"**. The model serves as a compass for defining and expanding upon the "WHAT" factor during the composition of the design brief, while promoting innovative thinking in terms of the "HOW". Though the model does not provide specific methods for the "WHAT" realization, it directs the user towards an ideal place of profitability alongside sustainability. In addition, the model expands upon the identification, examination and evaluation of new attributes that affect the scope of the project brief. Some of these attributes are sustainability attributes derived from the relation of ideality and sustainability. It also promotes creativity that stems from the use of a multidisciplinary approach. This creativity is necessary to manage changes and intricacy [12]. Furthermore, the model is flexible and can be adjusted to various projects by changing the design brief being examined. The objective of the model is to develop the "WHAT" as a crucial, strategic asset that allows the designer to reach decisions, by selecting the relevant attribute for the objective and target audience. The model provides systematic expansion, capable of adapting to every user scenario method, even prior to application of the Bio-mimicry process (7), and serves as an in-depth, revolutionary approach in the design brief formulation process. Designers that work using a flexible method tend to produce better solutions [4].
While the client's brief is a tool for coordinating expectations, specifying constraints and a maintaining a platform for collaboration between the designer and the customer, the design brief describes and explains the design problems and lays out their significance and any possible solutions for the defined objectives. It serves as a map of the future product, allowing for optimization as early as the design stage. Therefore, the model is important and bears significance in the formation of the design brief. The brief determines the distance to the objective while the designer determines the manner in which that objective will be reached [13]. Consequently, it is crucial to keep the brief updated throughout the

project with any insights and decisions that arise and that might affect the quality of the project. The solution though is always performed within the design brief.

The "WHAT" model is solution-oriented. Solution-oriented strategies have proven to be the most effective methods for handling design problems that have been ill defined [2]. It is also function oriented, increasing useful functions and decreasing harmful functions, based on the ideality framework.

These model characteristics mentioned above suggest a new design approach that can address the fast-paced changes, complexity and sustainability demands that exist today.

3 SUMMARY AND CONCLUSIONS

The “WHAT” model is a Bio-inspired ideality tool that can be used by the product designer to formulate and fine-tune the project brief according to the “ideality" strategies and principles found in nature [6]. This tool can be adjusted to create an ideal product design brief by serving as a compass for focusing on the “WHAT” essence of a design and improve the analysis and synthesis stages. The check list helps the designer form more in-depth strategies and concepts for an ideal design that is well correlated to sustainable design. As we define the model's initial attributes, it exposes us to alternative innovative implementations, which as a result create a wide platform depicting the possible methods for reaching the “HOW”. This aspect of the model serves as the means for finding a stand-out solution that integrates the values of sustainability into society. The model is built from a methodical approach and is appropriate for B.Sc. students of Product Design. Students of Mechanical Engineering may also benefit from this model. Innovation in sustainability projects certainly stand to benefit from this model by improving the thinking stages based on Nature’s wisdom.

4 SUGGESTIONS FOR CONTINUED RESEARCH: FROM NATURE TO NATURE

The "WHAT" ideality model stems from a bio-inspired approach and ends up with a Bio-mimicry approach. We suggest further exploration of the integration of the Bio-mimicry approach (stage 7 in Fig.3) to address design challenges defined by the "WHAT" model in the product brief in order to reach ideal form and function. More studies are required to evaluate and expand upon the "WHAT" model for different fields including architecture, and other engineering disciplines.

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GATHERING STRUCTURED REFLECTION IN THE FURNITURE BUSINESS BY TREND MAPPING

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ABSTRACT
Setting up the direction for new product designs in the furniture business can be more or less structured and in many situations the idea for new design concepts, constructions, details, colouring or choice of material are directed by random input from retailers or external designers or from studying trend agency reports besides considering other matters like new market strategies etc.
In this paper the authors describe a methodology to create a richer discussion among the manufacturer and the retail partners based upon a collection and structured play/interview using research data collected by design students at an international furniture fair. The first test version of the method was developed and carried out by design engineering students and design researchers in collaboration with a furniture manufacturer and the results and methodology are presented and discussed in this paper.

Keywords: Trend mapping, trend analysis, furniture design, design communication, design engineering students.

1 INTRODUCTION

1.1 Should industrial designers care for trends?
In the history of furniture design, technology and aesthetics have been developed hand in hand with cultural, behavioural and architectural changes, and such aspects are still in play when designing conceptually new chairs or redesigning existing ones. Earlier radically new products like the Wiener-chair [1], the Mies van der Rohe 'Freischwinger' [2] were based upon the exploitation of new industrial production technology at a time where most furniture was manufactured locally at a slower development speed and only smaller details would differ from year to year. The same tendency can be seen through the 20th century where conceptually new chairs in plywood or integrated carbon fibre structures were presented along with variations of (now) older or traditional furniture designs.
The global furniture consumer can now choose among a huge variety of products and subtle details like colours, surfaces and style has become important factors along with basic functional requirements [3]. Even ethical considerations are becoming more important for the global consumer [4].
While the history of design and furniture is well described in literature, only few academic publications deal with the consumers choice of furniture or the decisions that lay behind the manufacturers strive to constantly present new product concepts or variations of existing models. Burnsed & Hodges, claim that "although the home furnishings case goods industry is a significant consumer goods market, little academic research has been conducted. To date, general home furnishings research has primarily been conducted by industry, government agencies, and lobbyists. Consequently, not much is known about the home furnishings case goods consumer. Few academic studies have addressed what is important to the consumer when making a home furnishings consumption choice." [3]. Most furniture manufacturers today rely on the input from external designers or the efforts and observations of an in-house R&D-department when developing new products. Some furniture manufacturers even buy expertise from trend-agencies when deciding the colours for the next collection, hence following a tradition known from the textiles industry (fig.1).
It is hence important for furniture-oriented industrial designers to be able to master the conceptual design approach along with the ability to integrate the current and rising trends in culture, aesthetics and technology.
At XX university we have for 15 years run an industrial design academic program with much emphasis on strengthening the students' conceptual design approach while more or less neglecting the

trend-aspect or furniture in general. Last year industrial design candidates from XX university won the two most important national furniture competitions hence making us aware that we could focus more in this area while at the same time developing tools to improve the manufacturers communication with customers, designers and retailers on this matter.

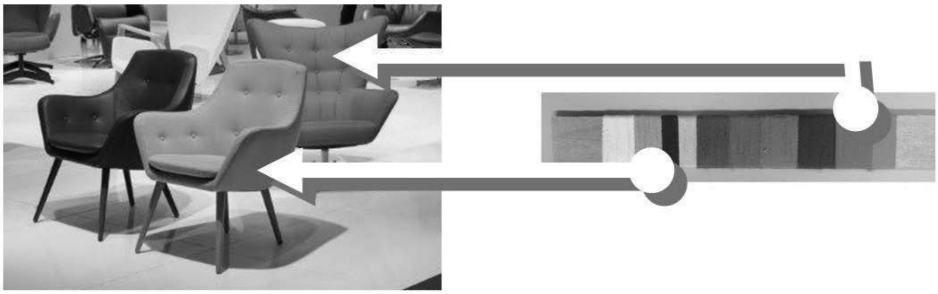

Figure 1. Colour-scale recommendations from the Trend-agency and manufacturer X's new product presentation at a 2015 furniture fair

1.2 The main furniture trend categories

To put more focus on the topic of trends in the furniture industry we have been observing international furniture fairs from 2013-15. Every year a group of 130-140 students were sent to the Salone del Mobile in Milan to observe and report '*phenomena in form, surfaces, details, materials, general compositions etc. which can be said to express a current or new trend'*. Early results of this research was published in [5] and these results were sorted and later reduced into 6 main categories that are partly overlapping.

It is important to notice that the categories not only deal with aesthetic elements but also construction principles and more technical matters like manufacturing technology, hence covering a broad range of perspectives relevant for *integrated design* practice and education[6]. The main categories were:

1. Materials & Manufacturing methods
2. Surface, Colour & Texture
3. Form, Structures & Elements
4. Green/Environment
5. Thematic Form Concepts, Motives & Details
6. Product Categories & Use

An example can be seen on Fig.2.

The gathered trends do not represent an objective truth per se and some of the trends might already be fading, but the material has been useful as a turning point in discussions with industrial design engineering students at different levels. This experience lead to the idea of testing the use of such trend registrations as a tool for communication and clarification involving a furniture manufacturer X (see fig 1) and its retail customers A&B.

2 TREND REGISTRATION CARDS AS A COMMUNICATIVE TOOL

2.1 The Trend Discussion-system

While colour maps or trend reports from professional agencies can provide more or less structured reports on aesthetic tendencies and phenomena gathered by external researchers to use by the furniture manufacturers, such reports do not automatically provide company communication with the end-user or the retailers. We therefore wanted to test if the above mentioned trend mapping by industrial design students could in any way be useful as a tool to enhance communication or at least clarify differences in stakeholder views. In this first test-case we focused upon the retailer/manufacturer relationship and got in contact with company X and they allowed us to contact the retailers A&B to test the Trend-Discussion-System on both parts.(Table 1).

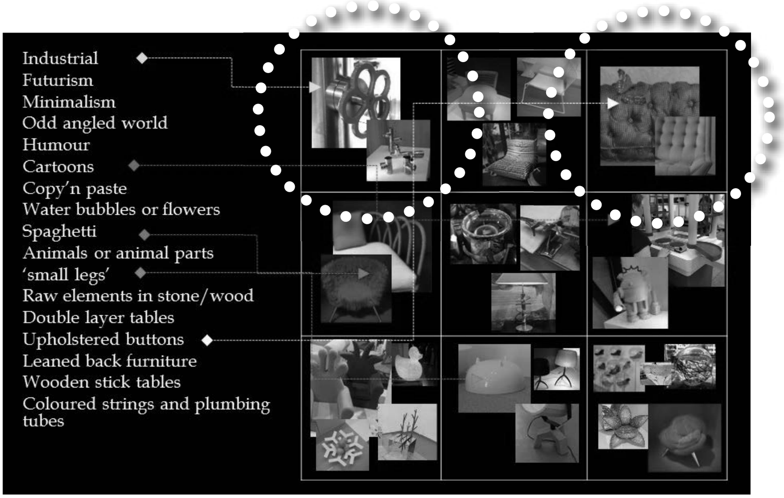

Figure 2. Example on students' Trend Registration theme 5: 'THEMATIC FORM CONCEPTS, MOTIVES & DETAILS. The trend 'Industrial' is illustrated in circle top left and 'Upholstered Buttons' is illustrated in circle top right

The test-system consisted of only few elements:

- 16 cards sized 8x8cm each with a picture of one variety of trends from category 1-6 mentioned in chapter 1.2.
- An A3-board picturing a simple arrow-formed scale ranging from 0-100%

The system was hence presented in different tests with 5 different persons, who were individually asked to situate each card according to a range of questions like:

Q1: Are there any trends that will disappear or become more prominent? (in general)

Q2: 'Which trend/trends would you prefer company X to implement in new products? (the specific manufacturer X)

Q3: 'What will be in the market in the future? (at the specific retailer)

Each individual test would take less than one hour and questions with identical focus were given to all participants but leaving place for the test-persons to comment or argue for their ranging according to each topic. The test-persons were also given the possibility to write additional cards themselves if they needed more topics. This option was used a couple of times by the retailer representatives.

The five test situations were made individually with the following persons:

Table 1. Test persons from company X and retailers A&B

Industrial designer at manufacturer X
Product manager at Manufacturer X
Store manager at Retailer A
Purchasing manager at Retailer A
Store manager at Retailer B

2.2 The test results

When all the cards were positioned on the 0-100 scale-arrow the interviewer noted the position of each scale and made graphic representations for later analysis, where 0 is to the left and 100% at the point of arrow. Simplified examples of the representations of the scales can be seen on Fig.3, 4 & 5.

3 INTERPRETING THE MAPPINGS

3.1 The sub-categories

The following interpretation of the mappings are based upon the different test persons ranging of the cards on the scale-arrow and adjusted by supplementary verbal comments given by the test persons during the session. We have chosen a few categories out of the 16 cards that most clearly show similarities and differences in the choices of each test person. The sub-categories and the abbreviations used in fig.3-5 are:

- *Multi functionality*
- *Industrial look (see fig.2)*
- *Weaved structures*
- *Pastel colours*
- *Upholstered buttons (see fig.2)*
- *Felt*

These categories cover a broad variety of the main trend categories mentioned in chapter 1.2 meaning that trends in colour, materials, structural elements and thematic form concepts are represented in the above mentioned sub-categories. The following cases describe possible explanation and interpretation of the illustrated results.

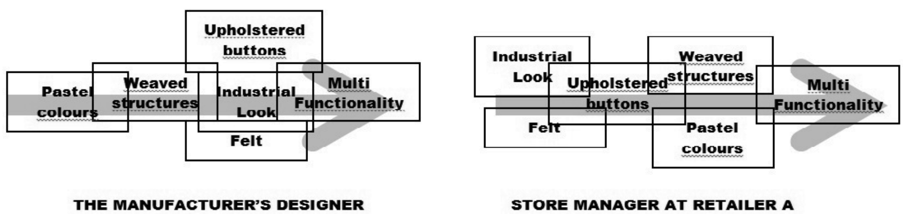

Figure 3. Representation of 2 respondents' priorities concerning Q1: GENERAL TRENDS

3.1 General furniture trends rated by industrial designer and store manager

When looking at fig.3 referring to question 'Q1' it is clear that the manufacturer's industrial designer (left) and the store manager A (right) agree upon a coming desire for more multifunctional furniture *in general*. It also seems like they both expect the trend in 'upholstered buttons' and the 'industrial look' to be relevant in the coming years. While the industrial designer has more attention to the use of felt in future products it seems like the store manager does not fully agree that this is a strong trend. He believes more in pastel colours while the industrial designer seems to rate this as a fading or unimportant *general* trend by rating it lower. The same pattern is shown when it comes to the weaved structures trend, where the store manager added, that he himself saw a huge rise in products at different occasions from lamps and chairs to sofas etc. while the industrial designer found that rather uninteresting.

3.2 Trends for manufacturer x rated by id & purchasing manager

When looking at fig.4 referring to question 'Q2' the question aims to clarify which trends the manufacturers industrial designer (left) and the purchasing manager A (right) expect to be relevant as future trends for the *specific* manufacturer (X). The designer and the purchasing manager are directly involved in deciding which trends to implement in future products from manufacturer X as company A is an important retailer. It is therefore fruitful if they agree on this direction. The designer found 'upholstered buttons' being very relevant for the furniture manufacturer in the near future while the purchasing manager estimated that this particular trend had been used much already and should not be given more attention. The 'Weaved Structures' also was prioritized differently as the purchasing manager thought it would be interesting to see also in chairs while the industrial designer saw no possibility to make such products in the current manufacturing set-up, although he did not ignore the trend totally. They both agreed that 'Pastel Colours' should be available in the future portfolio from company X, and the ‘Multi functionality’ was highly prioritized as well. This trend or feature has traditionally been given a high priority in company X’s product portfolio on reclining chairs and the high priority of this topic by both respondents therefore might just emphasize a recommendation for manufacturer X to follow the existing product policy and not necessarily to add even more multi functionality.

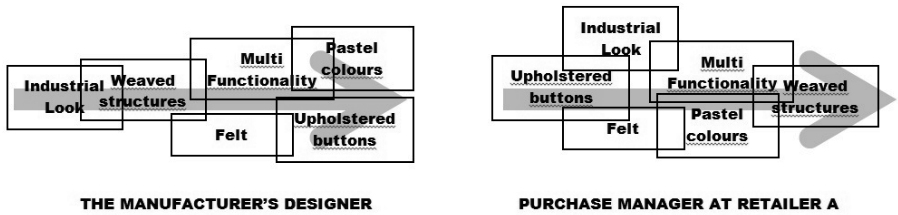

Figure 4. Representation of 2 respondents’ priorities concerning Q2: Preferred trends for manufacturer x

3.3 Trends in the future rated by product manager and purchasing manager

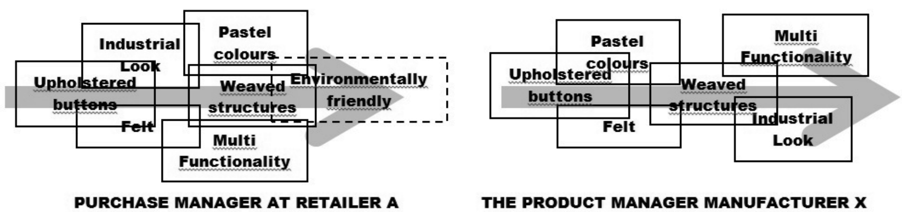

Figure 5 . Q3: Preferred trends for the specific retailer/store

We also tested a situation, where 2 different persons were asked to individually use the rating scale while the other person commented simultaneously. This situation created a much more lively conversation with more detailed topics being exposed. Fig.5 shows the ratings by the product manager from manufacturer X and the purchasing manager from retailer A concerning the trends that were relevant for retail store A in the future. Both agreed upon the position of the ‘Upholstered Buttons’, ‘Felt’ and ‘Multi functionality’ cards. They disagreed about the position of the ‘Industrial’ card, where the product manager found it very relevant while the purchasing manager rated it lower. The clearest difference in opinion was exposed when the purchasing manager stressed that *environmentally friendly* products would be highly relevant when choosing products for their stores. He therefore insisted on adding a new card on this topic and placed the ‘Environmentally Friendly’ card as the top priority in his rating. On fig. 5 it is represented by the box with the punctuated outline.

4 CONCLUSIONS

4.1 Evaluating the method and results

The aim of this process was to test whether a huge amount of trends observed and reported by students could be transformed into a tool that would clarify similarities and differences in the rating of different furniture trends as seen by an industrial designer and other stakeholders.

The intention was also to enhance the communication on such matters between the different stakeholders by discussing the different mappings with them. Improving this communication might help the industrial designer and the manufacturer to more precisely refer to and pick up current trends and expectations from future customers and integrate such aspects in future design proposals.

This test was the first attempt to use the set-up and not all of the intentions were successfully honoured. Only one company and 2 retailer companies were involved in the test, but still a variety of different attitudes and priorities were exposed in a simple and transparent manner. Of course they only expose a limited variety of matters that count when deciding which products to design or to purchase for the store. Price, safety, terms of delivery and other matters are highly important aspects to consider when making decisions in this field.

Nevertheless it is our opinion that the method itself is so promising that we intend to follow up on this pre-test and set up a broader and more trustworthy -test with more manufacturers and in such case we also intend to follow up on the mappings by more in-depth interviews with the stakeholders when confronting them to the mappings made by the other stakeholders interviewed.

Even though the specific trends were presented on the cards with a photo-collage and a short headline, the system still to a great extend depends on the interpretation by each test-person. The sub-topic 'Multi functionality' can have many meanings and a deeper interview could have clarified any conflicting interpretations of this topic. It is therefore important not to see the mappings as true representations of the rating of future trends. The mappings should be seen as a discussion platform that also inspires new insights in a playful and involving way. This intention was most clear in the situation where the Purchase Manager (see fig. 5) made a cart of his own claiming that ECO-friendly furniture might be the most interesting future trend to follow. This act made clear that the 'truth' not necessarily lies in the mapping itself but maybe *in between* the *different* mappings and the discussions. The authors find this approach important when dealing with such delicate matters and a point to keep in mind for future industrial design students or professionals who might try out the method themselves. .

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SKETCHING AS A THINKING PROCESS

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ABSTRACT
Sketching is a form of communication and as such particularly effective for illustrating ideas or sharing thoughts. For designers, sketching is an indispensable tool that helps them externalize concepts, explore ideas and solve problems. However, the underlying principles of the cognitive creative process appear to be difficult to grasp. Students use sketching to visualise ideas, yet many do not know how to use it as a thinking tool. As a result, they tend to skip parts of the development process: the doodling, exploring, comparing and assessing that help them refine the initial intent into a mature design. To address this shortfall, a methodical approach to structuring exploratory thinking was introduced into a classroom and studio setting of the 3rd year industrial design program. The exercise described in details was initially developed for a theory course as a means of assessing students' ability to assimilate theoretical notions and apply them to design. In fact, the approach proved to be useful far beyond its initial scope. Students learned to externalize their thoughts, methodically explore creative options, as well as distinguish between common and unique. Many recognized how generating ideas in quantity enables the less interesting ideas to be discarded, paving the way for the emergence of creativity. This paper describes in greater detail de exercise developed for this purpose, observes and examines the challenges students face in transitioning from visualization to creative thinking mode, and comments the obtained outcome.

Keywords: Sketching, creativity, design development, Gestalt psychology, principles of perceptual organisation.

1 INTRODUCTION

Over the years, we continually observe students struggle with the creative process, especially with sketching, exploring and developing ideas into mature designs. Many see sketching only as a means of visualization and rarely know how to use it as a creative thinking tool. The proverbial 'fear of the blank page' seems to amplify this phenomenon.

Although, students are taught that doodling and sketching help them not only to "… think differently, generate a variety of ideas quickly, explore alternatives with less risk, and encourage constructive discussions" [1], only few actually develop these skills sufficiently. As Brown explains: sketching and doodling "can serve a myriad of functions that result in thinking, albeit in disguise" [2], he also suggests that they help enhance focus; increase information retention and recall; activate the 'mind's eye'; enhance access to creative problem-solving, and unify three major learning modalities: visual, auditory, and kinaesthetic [2]. In fact, sketching, when used to explore and materialize ideas as well as externalize thoughts, is critical to a designer's reflective practice [3].

Yet, thinking while exploring is a process difficult to instil and its intellectual dimension is widely ignored. The simple notion of trying, discarding and starting over seems to many students abnormal or a sign of failure, and not always readily accepted as a part of designing. Consequently, as soon as a sound idea emerges, students abandon sketching and hasten to the next visualization mode. In so doing, they neglect to explore variations and nuances, imagine new functions and features or envision the product in a different material or under a different manufacturing process. The developmental stages that include assessing and refining the initial idea are thus shortened or even disregarded, leading to ideas that are immature and less substantial.

With a wide variety of methods and tools at their disposal, students should be better equipped than ever to tackle design problems. Digital tools in particular have added a new dimension to designing.

However, in changing design practices, digital tools have adversely affected education. Firstly, each new tool needs to be taught and mastered, and as their complexity increases, so too does the effort of mastery. Given that sketching alone can already be a challenge, adding a technological component only complexifies the task. Furthermore, the growing spectrum of tools adds to the teacher's responsibilities. To incorporate these tools into the program, existing content must be adjusted, replaced or dropped altogether. In the case of sketching, students grasp the required notions only superficially, finishing their schooling with an inadequate skill set and a sense of ineptitude. Those with high ambitions and strong self-motivation manage to overcome the deficit; others learn to mask their lack of skills in one area by developing others. In our experience, the more gratifying digital tools gradually replace the doodling, sketching and physical mock-ups that are so fundamental to the development of a design and the decision-making process.

The second notable trend is that less and less time is committed to imagining, exploring or developing ideas and more time to visually enhancing or embellishing them. Powerful imaging software helps transform rudimentary visions into something polished, giving the false impression of a 'finished' design. Consequently, the outcomes tend to be either without depth, ordinary, and sometimes naïf.

Our observations indicated a third dilemma. Students have difficulty transitioning from the unrestrictive ideation mode into the discriminatory concept-development mode, proving that the development process is widely misunderstood or inaccessible. Indeed, students frequently stagnate between these stages and, in the end, habitually produce only cleaned-up versions of their initial ideas instead of mature and thoroughly considered concepts.

Understandably, initial ideas tend to be naive, unoriginal and lacking in depth. To stimulate the imagination and open the mind requires playful exploration. Given time, a critical approach and liberal doses of imagination, ideas can evolve into mature concepts that meet the established design objectives. Yet when absorbed in the creative process, students tend to lose track of the design goals. Sketching is also easier said than done. Whenever an idea is challenged, students simply change direction instead of creatively resolving its weak points. Many simply don't know what to do with the feedback or how to explore options and variations. Advice to develop an idea further is usually interpreted as 'continue searching for another'. Thus, when students encounter a problem, they simply abandon one idea for another.

The key role of doodling and sketching is insufficiently emphasized; similarly, the constructive thinking mechanisms that could help students approach the process methodically are often overlooked. Creative exploration needs to be structured to allow students to assess and discard initial ideas before advancing onto the next. This avoids the random accumulation of unjustifiable concepts, thus giving students a sense of how the design develops.

A vast amount of literature debates design methods and the role of visualization tools in design. This paper adopts a didactic perspective by presenting sketching as a thinking tool and examining how a structural approach can be used to guide the creative process. We will look at the learning challenges and propose a pedagogical approach to help overcome them.

Our structured approach was part of a theory course entitled *Semiotics and Design*, which explores Gestalt theory [4], and the laws of perceptual organization [5]. In the following sections, we will describe the framework of the exercise and its goals in greater details, explain the process, present the results and comment on its pedagogical value.

To ensure a shared understanding in reference to sketching and creative exploration, we will include modes of visualization that help externalize ideas (including formal and informal, physical and virtual, and two- and three-dimensional representations), provided they have been considered and used as a creative thinking tool and that their mode neither limits nor dictates the outcome.

2 THEORETICAL CONSIDERATIONS

Many consider the act of designing as a form of communication whereby the designer constructs meaning by defining the product's features (intended meaning), and the user perceives and interprets meaning when interacting with the product [6], [7]. Human-oriented design in particular focuses on the intuitive use of products, systems, spaces or interfaces. Accordingly, some design schools see the need for teaching the theoretical foundations of cognitive processes, semiotics and product semantics [7]. Gestalt theory and the principles of perceptual organization [8], [9] are already fundamental teachings in art and visual communication. Engaging users on a cognitive level, these principles are used to construct meaning, hierarchize messages, and emphasize or de-emphasize certain features. Gestalt theory emerged in the early 20^{th} century in the course of research on human perception conducted by Wertheimer, Köhler, Koffka, and Gibson, [4], [8], [9], [10]. The theory explains that objects in an environment are not perceived as individual parts but rather as global constructs and meaningful arrangements. Thus, the mental and physical act of *gestalten* (German for *form giving*) produces what is referred to as a *Gestalt* or a 'whole' with an internal structure. According to this theory, the stronger and distinguishable the Gestalt, the more memorable the whole. According to the research, innate perceptual laws govern the perceptual process and help people to interpret sensory experience [9], [10]. Grouping is indeed a mental strategy that helps simplify complex sensory experiences (sight, smell, taste, sound, touch, behaviour, etc.) into cognitively digestible portions in order to minimize cognitive effort (cognitive economy) [11]. Among the most representative Gestalt laws are those of simplicity (*prägnanz*), proximity, similarity, closure, figure and ground, good continuation and common fate. For example, the law of simplicity explains the human inclination to perceive complex and irregular shapes in the simplest manner possible by cognitively simplifying them as identifiable patterns (minimal, geometric, symmetric); the law of closure refers to the human ability to recognize and mentally complete a Gestalt (shape, poem, melody) with only fragments of information [4], [5], [6].

While these laws apply to all types of sensory stimuli, they are typically associated with visual perception. Nevertheless, it should be remembered that multi-sensory experiences (flavours, scents, textures, sounds, tastes) as well as thoughts and behaviours can be complex and are thus perceived and interpreted according to the same principles [4]. In design, this awareness can help designers become more conscious of their decisions, justify their design choices and assess their ideas in terms of visual organization, simplicity, complexity, ambiguity, etc. By exploiting perceptual grouping concepts, designers can create intuitive products that users can more readily appreciate and manipulate.

3 STRUCTURAL APPROACH TO SKETCHING

The exercise described below was designed with three objectives in mind: 1) to methodically explore design concepts through a conceptual framework and thus develop a sketching approach; 2) to assess and build on a concept's visual quality, thus showing how a concept can evolve; and 3) to grasp and apply theoretical notions to design. In this sense, understanding Gestalt theory and its laws and assimilating them into the design process was helpful to the students.

The assignment entailed having students gradually transform an abstract element such as a line, circle or symbol, using a conceptual framework to guide their exploration. Students were asked to choose a simple element and 'play with it' by progressively creating patterns and configurations, then disposing them as shown in Figure 1. Students were allowed to use any form of visualization: sketching, collage, physical artefacts such as nuts, bolts or noodles (with photos taken each step of the way), digital tools such as Illustrator and so on. They typically began with a single element that they subsequently multiplied, arranged and transformed. To foster creativity and avoid predictability, the exercise required a significant number of configurations over a minimum of twelve pages.

During earlier iterations of the exercise, only two pages showing the most unique configurations were required; consequently, only a few students took the time to explore variations before compiling the two mandatory pages. The results were unimpressive, lacking originality and intellectual effort. Furthermore, many (whether intentionally or not) only reproduced the examples seen in class using their chosen element. By imposing a 12-page exploration with 9 to 12 configurations per page, students sooner or later managed to overcome the stage of mimicking patterns and eventually transitioned into a more methodical creative thinking mode. Some theoreticians refer to this phenomenon as creative 'emergence' [13].

To help organize and structure the exploratory process, students were asked to use strategies. For example, it was suggested to follow bi-polar concepts such as singular to multiple (progressively transforming an element by multiplying and grouping, thus create visual interesting structures). Other suggested concepts were: geometric to organic, orderly to chaotic, linear to surface, positive to negative, etc. Unaccustomed to such a structured and concept-driven approach, many struggled initially and jumped from one configuration to another. Others missed the point of the exercise by trying to take shortcuts. Those using digital tools tried to gain time by copying/pasting entire pages and modifying certain arrangements, thus neglecting the reflective component of the experience altogether.

Nevertheless, our observations reveal that only when students reached the point of wondering what else to do did they actually start experimenting, exploring and producing unexpected results. This 'tipping point' is precisely the aim of the exercise. Figure 1 shows a number of predictable configurations in the early stages, whereas further down the line, patterns materialize that cannot be easily imagined. The results produced by a methodical concept-driven approach as opposed to random illustrations are thus easily spotted.

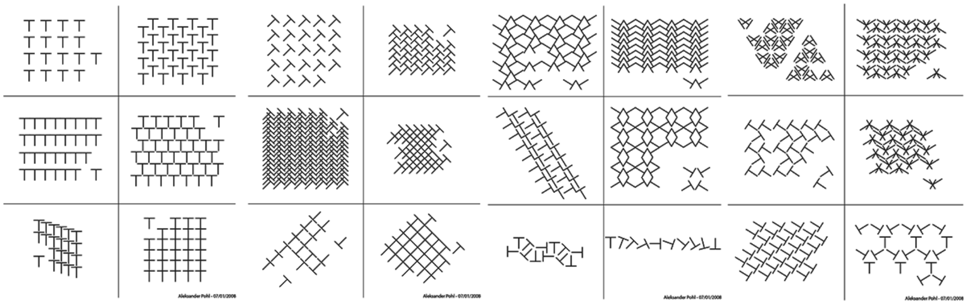

Figure 1. Example of a sequence (pages 11 and 12), by A. Pohl

Ideally, each new formation should be a refinement of the previous one, which implies drawing conclusions from a previous idea to inspire the next. To give a configuration more interest, one could exploit the visual phenomena of *dominance* or *emphasis*—for example, by isolating one of the elements, exaggerating its proportions, varying the spacing or simply adding contrast or an accent colour. The principles of figure/ground, simplicity, closure, proximity, isolation and so on were also used to assess the Gestalt quality of the proposed solutions or search for alternatives and nuances while refining and comparing the obtained results.

Among the 120 to 140 arrangements, students were to select the six most unique ones that they felt possessed the strongest visual qualities (Gestalt). Each was subsequently examined with respect to perceptible phenomena. By gauging each configuration in terms of its visual impact, originality, aesthetic quality, etc., students could reinforce their grasp of theory and demonstrate their understanding of the principles of visual grouping.

The exercise described above can be also applied in a more tangible fashion: for example, simulated perforations on a surface, textures and reliefs, printed elements and logos, spatial configurations or even arranging the buttons on physical or digital user interfaces to help identify and group functions and features according to a certain logic (menus, links, action buttons, etc.). However, while the tangible option was offered, students clearly preferred its abstract form. In any case, the exercise can be considered successful when students recognize a) the importance of following the conceptual framework; b) the need to produce in large quantities; and c) when they shift from visualization into the reflexive, experimental mode.

4 APPLICABILITY TO OTHER FIELDS

An exercise is only valuable when students grasp its purpose and learn to use the newly gained skills in their respective fields. Yet many tend to compartmentalize the knowledge and move on as soon a course or an exercise is completed. A systematic enforcement of newly acquired skills is needed to improve assimilation of the knowledge and help turn it into competencies. In this respect, some schools either link studio courses to their theoretical counterparts, thus making it possible for students to apply theory to design problems, or inject theoretical elements at specific stages in a given design project.

In our case, a 3rd-year studio class teaching *Product Semantics* was paired with the above mentioned theory course *Semiotics and Design*. The 16-weeks class allows students to apply the theoretical notions taught previously by learning to conduct a semiotic analyses of a user context, identifying and interpreting signs, defining the product language, categorizing existing products and analyzing their semantic qualities, and later applying Gestalt principles to design.

The given topic was 'time'. Using a justifiable form language, students were to come up with playful interpretations while focusing on the communicative aspect of design. Figure 2 shows a design exploration of an infant sleep timer, interpreted as a 'play-and-sleep buddy'. Figure 3 shows a kitchen timer that includes sound cues to signal duration, progression, etc.

In both cases, students began by studying the user context to extract information helpful for establishing design criteria, identifying relevant signs and analogies and so on. The ideation phase began with typical hesitations and random doodling as ideas were put to paper.

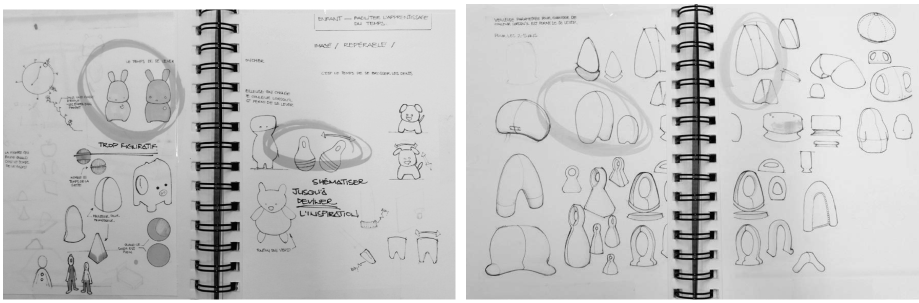

Figure 2. Random exploration turning into methodical evolution of an idea, by E. Perras

The goal of this exploratory and concept development stage was to seek viable solutions through sketching. As Cross explains: “The solution is not simply lying there among the data, like the dog among the spots in the well-known perceptual puzzle; it has to be actively constructed by the designer’s own efforts” [14].
Once the first two or three ideas were critiqued, students tended to change subjects, leaping from a shower timer to a USB-plugged computer timer, to detecting time in the wilderness, etc. To counteract this tendency, students were instructed to use the methodical approach without discarding their initial idea but rather learning from and building on the feedback. The goal was to understand the potential of sketching as a creative thinking tool.
The assignment was evaluated based on the following: the evolution of the idea, justification of the design choices, discrimination and refinement, the pertinence of the signs, visual cues and analogies used to express and communicate design features, etc. Figure 2 shows how a naive depiction of a children’s toy transitioned into a sophisticated interpretation, while Figure 3 shows how the idea for a kitchen timer matured into a design concept that communicates its sound features using visual cues.

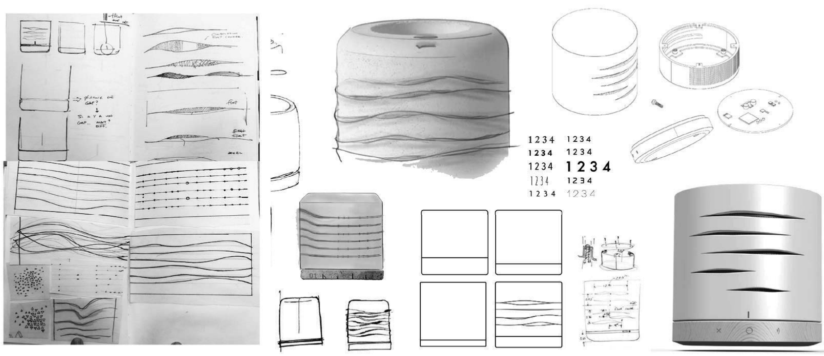

Figure 3. Methodical concept exploration of a timer design, by J. Croteau

5 CONCLUSION

Digital visualization techniques play a significant role in design—to the extent that, when entering professional practice, students are judged by their skills with these tools rather than their creativity or problem-solving ability. This unfortunately nurtures the misconception of design as an aesthetic gesture rather than an intellectual, creative thought process that helps solve problems and drive innovation. Many argue that there is little difference between drawing with a pencil on paper, a stick in the sand, or using a finger on a digital surface. Yet they tend to ignore the importance of visually comparing and assessing ideas side by side. When using digital tools, this aspect of the design process is easily overlooked unless the progression is systematically documented and digitally or physically compiled. Too many important issues come into play when assessing works-in-progress: concordance with design objectives, respect of functional, ergonomic, technical design criteria, visual impact and so on. Yet in the interests of efficiency, economy or ecology, these intermediate steps are being progressively eroded. In addition, it is a paradox to see students physically together in class yet working in isolation, completely absorbed in their individual screens.

Sharing, observing, critiquing and collaborating would appear to be less and less possible. The information that drives a student's thinking process is filtered and only the final realizations are presented. Digital tools allow ideas or concepts to be viewed only sequentially unless prints of every stage of the process are made. Even than, the process leading up to the final design is rarely documented. Digital sketching and presentation tools make it thus difficult to follow the design process of multiple students concurrently. Learning from one another and measuring one's own performance by comparing it with others are important to education; accordingly, these practices need to be valued.

For all of these reasons, design educators need to reassess the pedagogic relevance of certain tools to ensuring adequate design skills. Each tool must play its role at the appropriate time. The relevance of some should be questioned, while others may need reviving. Ultimately, it is vital that the adequacy of each be recognized within the design process, based on the tasks at hand. If tools embellish irrelevant ideas, camouflage problems and give students a false sense of accomplishment—or worse, are mistaken for 'good design'—then they may need to be called into question.

This paper set out to underscore sketching (including other forms of prototyping) as a tool for methodical exploration that can support the creative thinking process. By demonstrating some of the mechanisms involved, we have shown how a creative process can be structured, particularly when using a conceptual framework. Furthermore, the paper has shown how theoretical notions about cognitive processes, semiotics and Gestalt phenomena provide not only a solid basis when assessing the communicative value and Gestalt qualities of a design concept, but also a framework for structured thinking during the search for creative solutions.

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HOW DESIGN IS TAUGHT? A SURVEY OF APPROACHES, MODELS & METHODS

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ABSTRACT
How to teach design? This is not the first time that this question is asked and there are probably as many answers as design academic programs in the world. Knowing how to design is not enough to teach someone to do it. There are numerous experiences in this matter profusely published on literature. However, this information is sparse and does not exist in a summarized and comparative way, and knowing how design is taught is crucial to build other design academic programs in the future and enrich the pedagogical practices of the existing ones. Every design program should be based in a conceptual framework in which there are mainly two multidisciplinary fields: design and education. This framework provides a structured and concrete way of improving learning activities in design. In this paper, we will focus on design education identifying, summarizing and comparing its pedagogical practices (PP's) published in this matter. The first objective is accomplished with a survey of approaches, models and methods of teaching design (PW's), made from 204 publications not only in product design but in architecture, arts and other disciplines. A comparative table shows the name of the PP's, its conceptual foundations, the use of technology, role of the teacher and disciplinary origin. The second objective identified the elements in design education context to be able to describe relationships between them in the form of a pedagogical model to build in a future project.

Keywords: Pedagogical practices (PP's), teaching design, pedagogic methods, pedagogic approaches, pedagogic models, contextual elements of how design is taught.

1 INTRODUCTION

Product design academic programs should be founded on clear conceptual frameworks integrating design and education matters. However, this is not always the case due to the complexity of the elements involved in those programs. We believe that such frameworks should state clearly the main conceptual elements of the academic design activity: first, what design methods are and how one or more general design theories explain those methods (i.e. Yoshikawa's Suh's, Axiomatic design or C-K theory); second, models about the technological context, the user and the interaction to be incorporated in the product being designed and third, a pedagogical model of teaching and learning design. This paper presents then the first part of a future project intended to construct such a model. Having as future goal a more structured design program where each student's learning process is clearly justified, the choice and application of the teaching objectives and pedagogical tools are clearly settled, and the evaluative processes are supportive for the learner in his knowledge acquisition process. If such a framework is not clear, it's up to the professor's pedagogical skills to guarantee the success of the educational process. There are teachers who make it, there are others who don't.

This paper consists in a survey of methods, models and approaches published on literature to build these clear guidelines for the future. We understand a design academic program as a means that "enables the transition from the complete novice status of the beginner to the well-initiated status of the graduate designer" [3]. We've chosen this definition because it's not biased by a particular pedagogical stance and Pedagogy is defined by Oxford dictionary as the method and practice of teaching. A pedagogical model (PM) is a reduction and abstraction of the variety and complexity of elements and issues of the teaching process [6] with "a further level of abstraction of the learning activity"[7]. Teaching methodologies (TM) are specific guides to teach with a lower level of abstraction than a PM [8–10]. Lastly pedagogical approaches (PA) are those with a pedagogical stance but without any specific procedures or guidelines to teach design [11] (i.e. problem based learning sets the base of the education on the problem solving without saying specifically how this task has to be taught). One difficulty tackled in this survey was that educational concepts are named ambiguously on the design literature. This happens often with PM, TM and PA. This impedes the clear-cut analysis of the subjects found. We decided consequently to keep the PP's name given by the author in which it was found. Design knowledge would be "a body of information which provides an understanding of the principles, practices and procedures of design" [5]. In a broad way of understanding design, Gray (2011) defines it as "the activity we humans engage in when we are not satisfied with our reality and we decide to intentionally change it" [4]. When executing and learning such activity, the cognitive theories explain how the mind works in design knowledge acquisition and creativity's phenomena [3]. As Baughman & Mumford (1995) said, creativity is how people work with knowledge in the generation of ideas [2]. The first objective of this survey is to describe the different PP's present in literature, and the second, to identify elements of design education that aren't explicit in the PP's but are relevant to the understanding of its complex nature (i.e. gender, diversity, engagement, the who-how-where and what to teach, etc.). A deeper analysis of this information will describe design education in the form of a pedagogical model to build in a future project.

2 METHODOLOGY

In a first phase, we constructed a database with the literature, which was analyzed in the second phase. Figure 1 explains in detail the methodology followed. We used Qiqqa, a computer assisted qualitative data analysis software (CAQDAS), because it allows an effective classification and analysis of an important amount of qualitative information.

2.1 Construction of the database and its classification system:

204 publications were gathered on product design, industrial design, architecture, engineering and fine arts pedagogy books and design conferences papers (EPDE, ICED, DESIGN, TMCE among others). We looked for publications with a diversity of conceptual foundations and approaches to the ways design is taught. The search continued through the review of the publications referenced in each paper using Qiqqa's Google scholar real time connection and its TPR technology which recommends publications from a citation distance calculus. The search stopped when a saturation point was reached, i.e., when there were new publications but they failed to provide different information about the ways design is taught. Qiqqa counts with 3 AI tools allowing the software to divide texts into discourse units, calculate statistical proportions of keywords and approximate concepts from a large set of documents (Semantic Analysis) [13]. These tools make it possible to search and tag inside all the documents and make a useful, coherent and sufficient database mentioned before. The publications were classified manually using 99 tags (e.g pedagogical models, methods and approaches, cognitive tools, constructivism, cultural aspects, etc.). Those tags were extracted from the titles, keywords and abstracts of the publications and then confronted with the ones generated by Qiqqa automatically to filter ambiguities. Each time a publication was added to the database it could be tagged with already known tags or had new tags assigned to it.

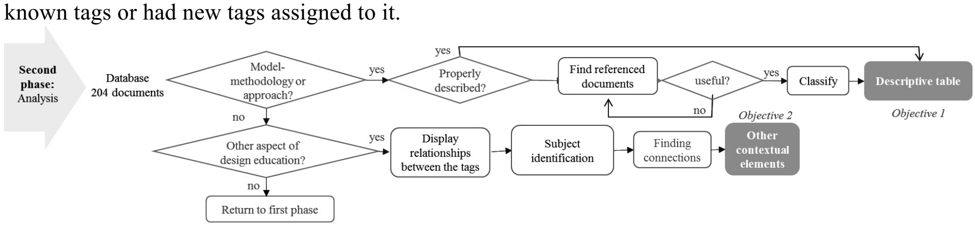

Figure 1. Database's analysis method

2.2 Analysis of the database:

This phase describes the PP's found in the database and identifies other contextual elements of how design is taught by analyzing the publications' tags (2nd paper objective).

2.2.1. Identifying the PP's to teach design

Papers with tags as Models (PM), methodologies (TM) and approaches (PA) were considered directly as PP's to teach design. The documents tagged were read to extract the following characteristics,

Table 1: name of the approach-model-method, conceptual foundation, use of technology when teaching, role of the teacher, design knowledge taught, and disciplinary origin.

2.2.2. Identifying other contextual elements of how design is taught

The tags used to categorize the database are grouped by design subjects (e.g. design methods and design tasks are part of a design group of topics). Then, Qiqqa's brainstorm utility displays the relationships between the documents as a net and clusters groups of papers with similar concepts.
The connections of this visualization (figure 2) are used to verify the group or subgroup assigned in the structure of topics shown in figure 3 (e.g. if the position of "Design for X" is unknown, the visualization shows the documents nearest to other design methodologies, so this topic is located in this group).

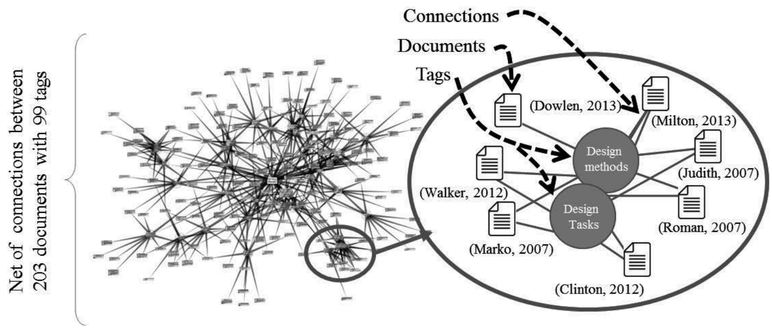

Figure 2. Issues to be taken into account and their relationship's visualization

3 RESULTS

3.1 PP's characteristics:

All PP's are featured through 6 characteristics: *1. Name of PW's*, with a high level of abstraction if it is M, lower if a TM or just an A. *2. Conceptual foundations* which are basic concepts or theories of each. *3. Using technology when teaching* are mentioned by its name, not specified (NS) or not mentioned (NM). *4. Role of the teacher* shows the pedagogical stance of the way design is taught. *5. The design knowledge taught* are design methodology (DM), a technological or contextual knowledge (K), or a particular skill needed to design (S). *6. The disciplinary origin*: a practice, a theory or a trend as source of the PP's. The PP's are on the same table because their limits aren't clear even by having different levels of abstraction.

3.2 PP's to teach design

Each PP's is described below and compared in table 1 with its corresponding characteristics.

3.2.1 Five pedagogical Models (PM):

1. Conceive-Design-Implement-Operate model, CDIO which produces "complex value-added engineering systems in a modern team-based engineering environment"[14]. Used for academic programs in Sweden, the USA and France [15]. 2. *Instructional models* are a set of models based on teaching by instructions, "typically specifying learning objectives and perhaps engage the learner in a project, assuming that he will understand and buy into the value of the problem" [16]. 3. *Kolb's experiential model* is a theoretical model based on the notion of experience as an organizing focus for learning from concrete experiences, reflective observations, abstract conceptualizations, active experimentations [11]. It's composed by two theories: Learning Style inventory (LSI); and the experiential learning theory[12]. 4. The *Studio model* is about design *skills* and behaviour. It's a "location where projects are individually or collaboratively executed, where projects are normally selected based on their applicability and conformance to the actual practice of that design discipline"[4]. *5. Reflective Learning Model* based on Schön's book E*ducating the reflective practitioner*. In which the conscious practice of design is enhanced: "reflective thinking generally addresses practical problems, allowing for doubt before possible solutions are reached" [17]. The student learns to be a 'reflective practitioner' engaging in his professional activity.

Table 1. Descriptive table of the ways used to teaching design

Name	Conceptual foundations	Technology Used	Teacher's Role	Design knowledge	Disciplinary Origin
CDIO Model	Standards/Rubrics/Auto-evaluation/ humanistic and technical skills	NS	Assessor	SK	Engineering practice.
Instructional Model	Plan-implement and evaluate	NM	Instructor	K	Learning theories.
Kolb's Model	Learning Style inventory (LSI) The experiential learning theory.	NS	Professor	S	Psychological studies
Studio Model	Design thinking, design skills, the environmental factors, social interaction, cognitive development and evaluation.	NS	Indirect instructor	DM/S	Art practices since renaissance.
Reflective Learning Model	Reflective practitioner (engaged professionals)/ book knowledge/ reflection-in-action (present) and reflection-on-action (past).	NM	Professor	DM	Epistemological focus- Rationalism
Situated learning (TM)	Learning environment / learner–environment interactions/ involvement/ choices of learning strategies	NM	Future client	K	Epistemological focus- Empiricism
Systems thinking (TM)	Complex problems and relations between its elements. Nonlinear thinking, team working, decision-making processes.	NM	NM	DM/K/S	Systems theories
Think-Maps (TM)	Design thinking, thinking process, ways of store and encode design knowledge, presence of knowledge (explicit or not), concept mapping.	WebPad	NM	DM	Epistemological focus- Constructivism
Project based learning (TM)	Driving question/ activity of designing/ formatively assessed and revised/ presentation of the project.	NM	Director	DM/K	Educational trends
Whole brain Approach	The brain of each person specializes in 4 brain quadrants: theorists organizers, innovators, humanitarians	NM	Professor Assessor	S/DM	Neurological studies
Learning by doing EA	Trying something/ seeing how well or poorly it works/ reflecting on how to do it differently/ trying it again and seeing if it works better.	NM	Guide	K	Educational trends
Problem based learning PA (PBL)	Presentation of the problem/ learners autonomy, small groups, resources available/instructor assessment/ content knowledge is acquired as needed/ reflection phase.	NM	Assessor, facilitator	S/DM	Educational trends
Strategies of experts EA	Problem perception/problem-solving-behaviour/ meta-cognitive knowledge/skills and cognitive strategies/ implicit knowledge.	N/A	Professor	S	Design practice

3.2.2 Four teaching methodologies (TM)

1. Situated learning TM is based on situated cognition theory. It posits that "learning is unintentional and situated within authentic activity, context, and culture. It has been applied in the context of technology-based learning activities that focus on problem-solving skills" [18]. *2. Systems thinking TM* was born from the need for a better way of testing social systems, in the same way we can test ideas in engineering [19]. It prepares "for interconnected thinking to deal with complex problems in a systemic, integrated and collaborative fashion–working together to deal with issues holistically, not simplistically"[20]. *3. Think-Maps TM* is based on the constructivism so "by constructing a conceptual map that reflects one's thinking in a domain, we make explicit the knowledge learned" [21]. This TM is focused on teaching how to construct knowledge related to designs, instead of constructing designs [21]. *4. Project based learning TM* is an instructional method based on the knowledge needed to solve a real problem while obtaining the skills to apply the solution.[10]. Teaches a particular method using knowledge and skills required in the project but other project, may need different skills.

3.2.3 Four pedagogical approaches (PA)

1. *Whole brain PA* criticizes education of the rational part of the brain omitting the rest of it. Everyone uses their brain in a specialized way originating "from socialization-parenting, teaching, life experiences, and cultural influences-far more than from genetic inheritance"[12]. 2. *Learning by doing PA* states that the most powerful learning always occurs when engaging in action. Engagement and experience are the most effective teachers. Involves learning by trial and error in safe environments [22]. 3. In *Problem based learning PA* "students direct their learning by working with and understanding the problem statement of the specific project. They are active in the knowledge acquisition and learn how to attack problems" [23]. *4.* The PA of *Strategies of experts in design* as Kesselring, and Pahl, describe how *s*ome design methodologies are developed by designers in their process of learning how to successfully design [24]. Therefore, this approach studied what they have in common and defines the skills that a designer should learn from an expert point of view.

3.3 Other contextual elements of how design is taught

The figure 3 is a proposal of a general view of design education context and its PP's. The elements in the reviewed literature are not explicitly connected with the PP's but, with further studies, could be found as important parts of the mentioned model to build in the future. This structure was constructed with the sematic analysis tool of Qiqqa as seen in figure 1. It presents 2 branches of design educational topics. The first, is composed by PP's (M, MT & A), philosophical affiliations (with constructivism as the most mentioned) and other issues (cultural aspects, students' engagement, etc). The second, shows *who* (agents), *how* (methodologies), *where* (learning places) and *what* (design knowledge: design process, tasks, methods as design for x or UCD methods, design tools, and skills, multidisciplinary aspects and HCI). The third branch shows the *cognitive topics* comprising: creativity topics and psychological topics.

Figure 3. Structure of design educational topics found on literature

4 CONCLUSIONS

The 13 PP's identified and described from literature can be compared in three characteristics: 1. Some PP's in which design is taught are *centred on the learner* (e.g. studio model, Kolb's experiential model, learning by doing, etc.) but there are others *centred in the design knowledge* to be learnt (e.g. Instructional model, CDIO, problem based learning, and expert's strategies). 2. There are ways to teach design based only on the *cognitive activities* involved in learning design (e.g. Systems thinking, whole brain model). Other ways are based on *other learning levels*, (e.g. humanistic and technical skills, the human senses and learning to behave and think as a professional designer). 3. *A professional profile* developed is shown when some models embrace the *diversity of the learners*, teaching them to find the design tasks of their expertise (Kolb's experiential model and whole brain) but somehow, others tend to form an integral designer (expert's strategies). The PP's have different sources: design history, the industry needs, the knowledge of experts in design and the scientific and philosophical theories from which the PP's were born. The PP's conceptual foundations are diverse: some describe their teachers as instructors, teaching by giving instructions to the students; others, as assessors to advice and guide their process; some have objectives as goals (Instructional PM) and others, have standards as guiding principles of the design learning process (CDIO PM). This shows deep differences between the PP's in need for the *construction of evaluative systems* that do not exist today. This evaluation, necessary to the further *construction of the model* sought, will be carried out in a next step of the future project. Questions are open for further studies along with the study of the relations between the cognitive topics and the design methodologies, and the epistemological structures (i.e. philosophical affiliations) of the PP's. It's important to highlight that this paper is limited to the information existing in literature; further studies will address other sources of information. However, this survey developed a large repertoire of possible choices when building a clear PP's for product design engineering programs. Further explorations will seek to find more about the product design methods and general design theories, creativity and thinking processes models and user-product-interaction-context models, their strengths and limitations.

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Chapter 19

Creativity

CREATIVE REDUCTIONISM: HOW DECREASING LEVELS OF INFORMATION CAN STIMULATE DESIGNERS IMAGINATION

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ABSTRACT
This paper reports on research that investigates how reduced information of an object may stimulate design students' creative imagination processes. Humans have the ability to recognise the meaning and to generate a complete image of an object as a representation from an incomplete image, as long as appropriate visual clues are given. If an incomplete state of an object can prompt design students to visualise 'representation completeness', element reduction might be utilised as a trigger for further creative imagination. In order to understand the behaviour of design students towards the proposed reductive approaches, two experiments have been conducted with industrial design students at Northumbria University School of Design. In the first experiment, the researchers observed how the design students developed their object imagination using images of an object whose quality was reduced in a variety of ways. In a second experiment, we observed how the imagination process of the design students was affected by reducing the elements of material and composition information of an object. This second experiment was conducted using scaled-down components of Gerrit Rietveld's famous Red and Blue Chair designed in 1917. These two experiments have revealed patterns of imagination processes that design students follow when they are given reduced levels of information. By understanding the nature of reductionism in design better, we may be able to develop a series of reductive techniques that will enhance the design student's imagination and stimulate their creativity.

Keywords: Reductionism, design, imagination, creativity.

1 INTRODUCTION

Humans are able to find meanings using their imagination when amounts of visual information are removed or reduced. Human perception is capable of identifying a complete image of a 3D object even if some parts are reduced or removed, as long as appropriate visual clues are available (Biederman, 1987). We recognise meaningful objects from meaningless low-level features of information through forming patterns in both bottom-up and top-down strategies of our cognition (Ware, 2008). Evidence also shows it is possible to imagine an object's semantic property in archetypal categories of existing objects effortlessly, even if only very small portions of the object are seen (Athavankar, 1989). We are inherently capable of finding meanings using our imagination and manipulating our knowledge structures when we are presented with incomplete visual information. This fact appears to indicate that a clear representation of an object's visual identity can be built in our mind even if the original image is unclear.

In the early stages of a design process, reduced quality in terms of visual clarity plays an important role in stimulating the designer's imagination. Reduced clarity of visual information leads to multiple interpretations of what is possible and that enables designers to explore ideas. Goel (1995) mentioned that ambiguity is a useful factor in the sketching activity of designers where they explore ideas. Goldschmidt (1994) asserted designers discover unexpected meanings within spontaneous relationships among depicted elements in their sketch. The unintended relations and features are discovered even from the designer's sketch drawn for other purposes, and it prompts them to generate new ideas (Suwa and Tversky, 2002). At the preliminary stages of the design process, ambiguity and incompleteness of information can be regarded as a key factor for idea exploration for designers.

The authors believe that reducing information has great potential for inspiring a designer's imagination and can be deployed as an effective tool in the context of design. In order to better understand how design students react with reductive approaches and how it impacts on their imagination processes, two experiments were developed. If incompleteness affects design students' imagination processes positively the reductive approach might be an opportunity to stimulate a designer's creativity. Thus, an important question is - what kind of elements do design students consider as significant for object imagination within a reductive approach?

2 THE FIRST EXPERIMENT

We conducted an experiment to observe the imagination processes of a group of design students when they are given images of an object whose descriptive information is reduced. The aim of this experiment was to understand patterns and characteristics in the design students' behaviour when given reduced levels of information in images. This study involved 17 undergraduate industrial-design students of Northumbria University School of Design. The group was composed of 4 students in the 2nd year and 13 in the 3rd year.

The study comprised 17 different types of image reduction of an everyday chair: animated, pixelized, dotted, removed, coded, outlined, pointilized, vandalised, cubismized, voided, technically described, painted, angled, sketched, dismantled, explored and roughly sketched (Figure 1). These exploratory image prompts were prepared randomly. The original image of the armchair used in this experiment was arbitrarily produced by the researchers. Accordingly, the participants have never seen this particular image of this chair before.

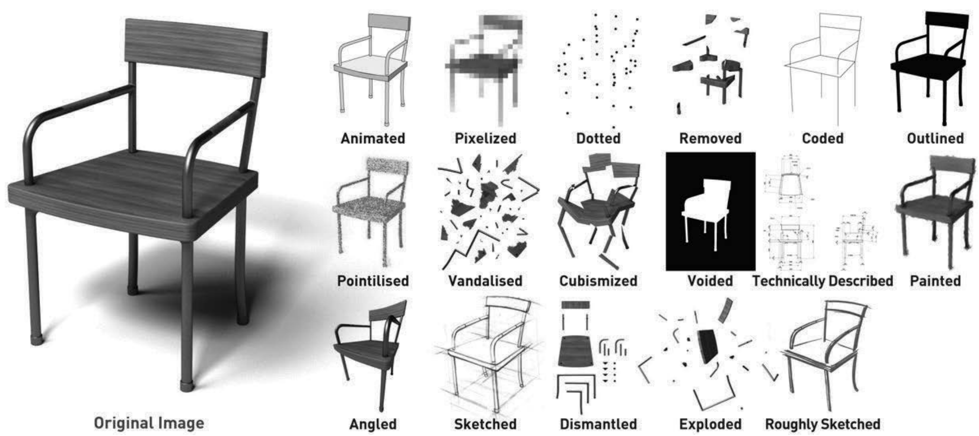

Figure 1. The original image of the chair (left) and the 17 reductive images provided for the participants

Each participant was given a specific reduced image, and asked to visualise the original object. The participants were asked to draw a sketch on an A3 sheet of paper and to make a model of what they imagined using materials provided by the researchers: A3 paper, pens, model making equipment and tools (e.g. clay, board, plastic sheet, balsa, craft knife, handsaw, pliers and glue). They were asked to complete all the processes within 30 minutes. After the completion of the drawing and model making exercises, each participant was interviewed (using a semi-structured format) to understand better their imagination processes.

2.1 Semi-structured Interview

The focus of the interviews was on exploring what kind of visual cues design students rely on for representation completeness when they imagine an object based on a reductive image. The participants were asked to respond to questions that focused on key themes such as:

- The first approach and the visual cues for sketching.
- The categorisation of the object they created.
- The reference to existing object.

2.2 Outcomes

Except for the participant who received the image of 'Vandalised', 16 students constructed a model representing a chair. Furthermore, 13 participants created chairs with arms, and 6 of these 13 produced models that are very similar to the original image of the object. A few outcomes (e.g. 'Exploded' and 'Dismantled') illustrate that the participants could build similar compositions of the object to the original even from the images where the components are dispersed. Only the image of 'Vandalised' in which the components are not identified easily enabled the participant to create a different object (desk) from the original armchair.

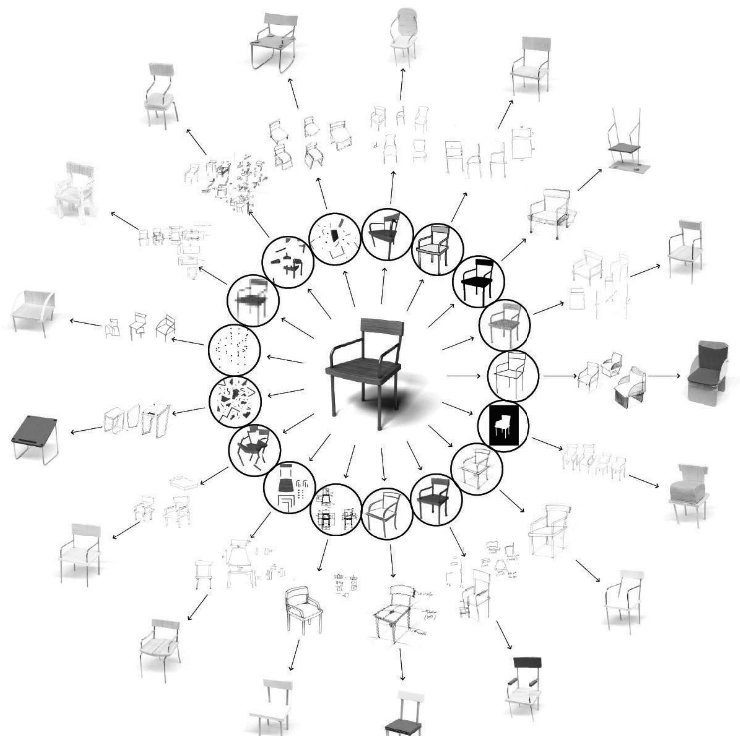

Figure 2. Development process including the sketches and the models of the 17 students

2.3 Findings

The transcribed contents of the interviews were analysed following a Grounded Theory approach (Glaser and Strauss, 1967). The contents were treated as raw data, and highlighted sentences were gathered and categorised through several coding processes. The results suggest that the 2 elements of 'materiality' and 'composition' played a significant role in the participants' imagination process inspired by the reductive images. Another fact the researchers discovered was the elements of both 'materiality' and 'composition' were heavily supported by prior-knowledge. In fact, many participants developed their imagination activating different types of prior-knowledge such as associations between particular colours and materials, past design experiences, general knowledge regarding the structure of objects, or understanding of the meaning of a specific component. Accordingly, the researchers proposed a framework of information based on the first experiment (Figure 3). The design students manipulated material and compositional information supported by prior-knowledge available in the reductive images to develop their imagination. In other words, this finding appears to suggest that it may be possible to prompt design students' imagination of an object by reducing the information of those 2 elements (materiality and composition).

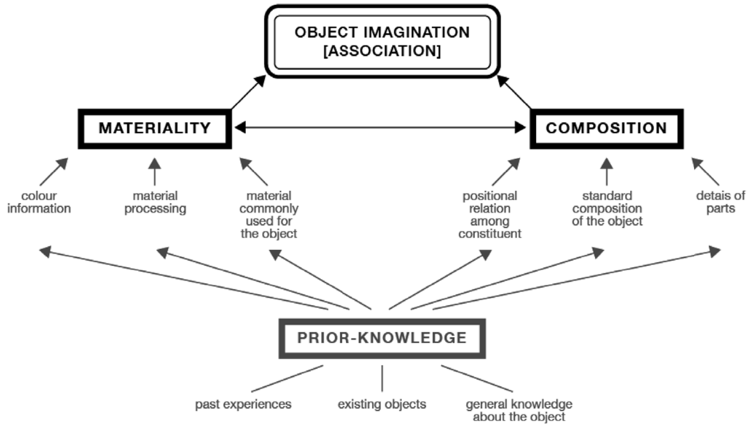

Figure 3. Framework that illustrates the elements the participants mainly used for their imagination process

3 THE SECOND EXPERIMENT

Following the findings of the first experiment, the researchers conducted another experiment. The researchers focused on observing how the imagination of the design students was affected by reducing the elements of 'materiality' and 'compositional' information of an object. Additionally, the researchers also observed how the reduction of these two elements of information impacted on the prior-knowledge of the participants (the analytical process of this experiment is currently in progress). The experiment was conducted using a one-tenth scale model of Gerrit Rietveld's famous Red and Blue Chair designed in 1917 (Figure 4). The parts of this chair consisting of simple linear material do not include any symbolic meanings. The researchers employed this object as a prompt for the experiment because this neutral characteristic enables us to focus on the differences of the participants' imagination processes in their reaction to various levels of reduction.

Figure 4. Red and Blue Chair designed by Gerrit Rietveld (1917)

In order to reduce the compositional information of the object, all the components were decomposed and arranged in the order of size. In addition, the material information was reduced with 3 different types of colours used (Figure 5). In the previous experiment, we learned that colour information is one of the significant factors that compelled the participants' imagination for materiality of an object (figure 3). Accordingly, the following 3 types of colour used here were;

1. Painted in the same colours as Rietveld's original Red and Blue Chair,
2. Painted in white that obscures material information, and
3. No colour information.

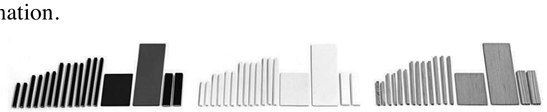

Figure 5. Provided 3 types of chair components (left to right – 1, 2, 3)

The components painted in the original colours offer some information of materiality to the participants and, therefore, it is considered as the most prescriptive prompt. Subsequently, the components painted in white give them less clues for the materiality of the object. Finally, the components whose colour is completely removed are considered to have the least information for the materiality of the object. This observation has been conducted comparing those 3 reductive levels.

In the experiment, 18 industrial design students of Northumbria University School of Design in the 4th year were involved, and each of the three groups comprised six participants. Each design student was given the components of the deconstructed chair and asked to make a 3D model of their visualised object. The experiment was conducted individually, and each student was interviewed after his or her model making exercise.

3.1 Procedure

This experiment has been carried out according to the following procedure:

1. The deconstructed materials were provided.
2. The instructor (first author) informed the participant that the materials are scaled-down components of an object.
3. The participant was asked to visualise the object, and then to create a model of it using all the given materials. They were allowed to take as much time as they wanted to complete the task.
4. The participant was interviewed after the completion of the model making exercise.

3.2 Semi-structured Interview

Semi-structured interviews were conducted after the completion of the exercise. The focus was on understanding the participants' imagination processes and the outcomes. The participants were asked to respond to questions that focused on key themes such as:

- The objects creation and the way the object would be used.
- The generation of ideas and what clue(s) helped in imagining the object.
- The object's materiality.

After being asked these questions, the interviewer (first author) showed the complete scaled-down model of the original Red and Blue Chair to the participants. Then, the participants were also asked to describe the difference between the object they created and the original chair. All the contents of the interviews were transcribed for analysis.

3.3 Results

The results appear to indicate that as the reductive level of the colour coding increases, the types of outcomes become more diverse (Figure 6). In the group of the original colours (top row), 4 out of 6 participants created a chair, and 4 of them referred to the original Red and Blue Chair. One student mentioned Charles Rennie MacIntosh's chair during the interview. This suggests that the colour information provided prompted the participants' prior-knowledge to this design masterpiece. Furthermore, all participants created furniture related objects such as a chair or a table. In the group of one colour (white), 2 out of 6 participants made a chair, and 2 of them associated it with the Red and Blue Chair in their imagination process. This result shows that reducing colours down to one made a difference to the outcome. In the group of no colour, none of the students created a chair nor refer to the Red and Blue Chair. Moreover, the outcomes were created in a variety of object categories from an industrial switch to a massive opera house. Thus, the greater the information given to the participants the closer their imagined and produced object was to the original. By contrast, the types of outcome became more unpredictable when the students were given reduced information.

The analysis process is still in progress and the data will be analysed using a Grounded Theory approach. Further analysis will illustrate what kind of factors impact on the student's development of creative imagination when the materiality and compositional information of an object are reduced. Moreover, the influence of prior-knowledge under such a reductive condition will also be examined.

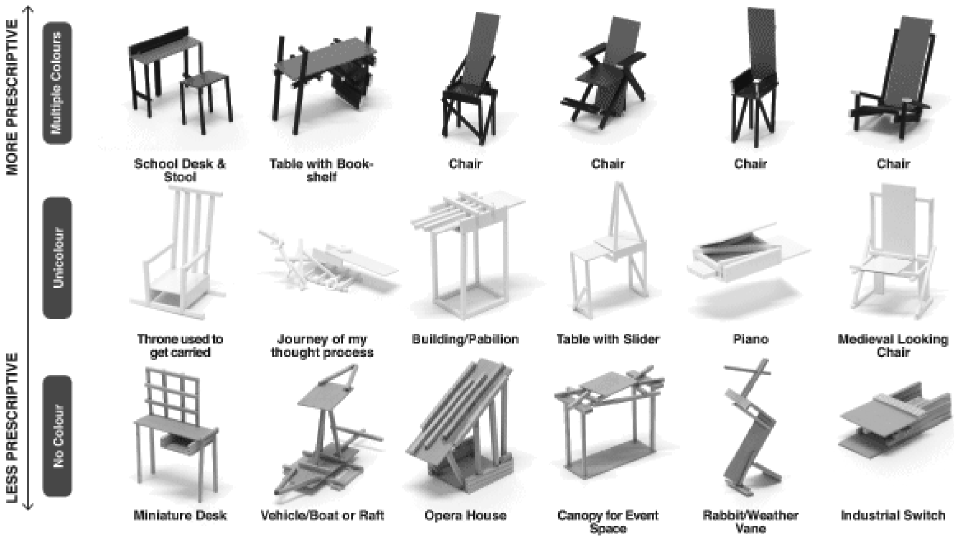

Figure 6. Outcomes

4 CONCLUSIONS

The results from both experiments appear to indicate that design students can develop their imagination of an object from reduced 2D/3D design prompts. The students considered the material and composition information of an object as a key element, and the reduction of these factors impacted on their imagination processes. The researchers also discovered that visualised outcomes became more varied according to the different reductive levels of material and compositional information of provided materials. A further study of the manipulation of reductive levels of these elements will contribute to the development of a tool for generating unpredictable ideas.

In the context of design education, providing too prescriptive design inputs (e.g. design briefs or visual prompts) may decrease students' creativity for imagination, and may lead them to predictable outcomes. On the contrary, giving them too little design-clues may not bring productive outcomes either. However, if the method is designed appropriately, a reductive approach potentially stimulates a student's creativity and offers diverse possibilities for their imaginative exploration. What is important here is finding out the optimum level of reduction of design inputs to prompt student's imagination.

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METHODS FOR IDEATION: REVIEWING EARLY PHASE CONCEPT GENERATION AMONG INDUSTRIAL DESIGN ENGINEER STUDENTS

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ABSTRACT
Developing and teaching method design remain an important component of many product design and engineering courses. Several scholars have shown that the use of ideation methods may result in better concepts. Yet students do not actively use many methods. In order to understand which ideation methods are used by students during the early phases of concept generation, we examined student journals kept during the length of a practice-based course where students worked on tangible interfaces. Students were not specifically instructed to use any specific method. Our study reveals that students use a limited assortment of ideation methods as part of the early phases of concept generation, often restricting themselves to unstructured brainstorms, finding inspiration from existing products and services. Our study raises questions about method use and education.

Keywords: Design methods, brainstorming, education, conceptual design, ideation.

1 INTRODUCTION

Method design remains an important focus of design and engineering researchers [1], with researchers continuously developing or adapting existing methods. Especially for young designers, methods may offer a systematic way of ideation or product development that leads to better design outcomes [2]. Among such systematic approaches, we find an assortment of tools aimed at finding (design-) inspiration and solutions through various ideation techniques [3]. Yet, while many developed methods may not be used extensively by students or practitioners [4], students still rely on certain tactics to help them create design solutions and education on methods is nonetheless taught widely.

To understand which tools design students use, we examined the chosen ideation methods of master level industrial design engineering students during a 12-week course where student teams developed tangible interfaces that go "beyond the desktop" [5]. Project examples include augmented reality prototypes in the kitchen, an installation for a public library, a nurse call system or improving an e-bike for postmen. Projects typically involve industrial design, and human computer interaction. Students are already familiar with a variety of existing design tools and techniques, having completed earlier courses on methods in design. Students were not specifically asked to apply any particular method during their design process and were thus free to use methods as they saw fit. Student-teams were asked to keep an online journal during the course. Each team catalogued all design decisions, benchmarks, meetings and design iterations. Our focus was specifically on ideation methods. Priority was thus given to the early phase of the development process where opportunities are identified [6], and the methods used to help refine the design task and lead to a choosing a final design focus.

2 BACKGROUND

2.1 Methods in higher education

Cross frames the rise of methods as object of inquiry as an attempt to make design more scientific [7]. Since the 1970's design methods has garnered much attention from scholars as a way to systematize design decisions, and many have proposed their own particular design methods. From the start of their education, students also get into contact with a wide variety of methods that should aid them during the design of products. Seminal texts introduce and review a variety of methods for "Finding and Evaluating Solutions", ranging between brainstorms, literature searching, or analysis of technical systems [3, Ch. 4]. Other relevant scholars in this domain include Cross [8, p. IX], who "offers a strategic approach and a number of tactics as aids for designing successful products". Efforts may also focus on better understanding the target audience or the context of use [9]. Similarly, Jones presents various techniques such as brainstorms, or morphological charts [10, Sec. 4].

These texts illustrate the emphasis on methods in design higher education. However, the focus on methods is not without criticism. For example, Dorst [11] remarks that surprisingly few methods are actually used by students, emphasising the importance of studying design practice. Rogers [12] also states that, while many theoretical approaches have been helpful in the scope of human computer interaction practice, uptake among practitioners remain low.

2.2 Related Studies

There have been various efforts at studying method use among design students. We provide a brief overview, first looking at selected comparative studies that highlight difference in - and value of - method use. Following this, we introduce studies that provide overviews of method use among students and practitioners.

Daalhuizen, Person and Gattol [4] compared the effect between systematic and heuristic methods on students experience. Significant differences were found between the two approaches, with systematic methods resulting in higher experienced time pressures and effort, and lower feelings of motivation. Yilmaz and Seifert [13] also looked at the use of heuristics by an expert designer, stating that through the application of heuristics, the designer expands his creative thinking.

Weaver et al. [14] compared two specific methods, the Transformation Design method and the WordTree Design-by-Analogy, showing that the Transformation Design method increased the quantity of ideas. The authors refrain from analysing the quality of the concepts generated by each of these methods. Also relevant is Lai, Honda and Yang's [15] study into user involvement, examining how involving users impacts design outcomes, concluding that iterative evaluation of concepts can be particularly valuable. This study contributes to these earlier efforts through reviewing the actual ideation method usage among students. In an additional comparative study, Genco, Hölttä-Otto, and Seepersad [16], conclude that method use by freshmen students, specifically, the 6-3-5/C-Sketch method (see [17] and [18]) yields results significantly higher than those by senior design students, suggesting that this particular method can be valuable in design practice.

While these studies offer comparative analysis of method use among students, others provide a review of tools and methods usually used by designers. For example, Stolterman et al's [19] provides a review of "designerly tools". While tools may not always equal to methods, the authors took a similar approach by cataloguing the variety of design tools used by master or PhD level design students. Examples include whiteboards, interviews, personas or brainstorming. Similarly, Biskjaer, Dalsgaard, and Halskov [20] provides an overview of tools often used by interaction design students. These studies highlight the value that method use may have and the uptake among students. We further contribute to this work by providing insight into the actual use of methods among master students.

3 METHOD

3.1 About the course

As part of their master education, students at our department were tasked with the development of tangible interfaces that go "beyond the desktop" (see [5]). These projects typically involve a certain degree of interaction and interactivity. Students were presented with cases, some of which proposed by local industry, and others linked to on-going research. Students could choose three cases in order of preference. Following this, students were assigned a case. Groups are limited to 4 students, with most containing 3. They are asked to keep a journal of their process, meetings, technical issues, ideation processes and early prototypes. Results are finally documented in a short paper. Students are all in their 4th year and have thus already finished their graduate (Bachelor) degree and are currently enrolled as Master Design Engineering students. None of the participating students were international. The education in the Bachelor program offers courses on ideation and creativity techniques, user involvement and problems solving.

3.2 Data collection

We focussed on the online journals of each team (n=15). Their journal was analysed for mentions and descriptions of ideation methods and techniques. The emphasis was on the first weeks of the course, when there is a strong emphasis on ideation. However, in some cases (#5 and #15), ideation extended beyond early phases and here, analysis was continued until the final concept was identified. We focus on the journal and paper, since this documents their design process and captures the various methods they themselves feel are most valuable. Results are categorised into explorative and generative phases, following Finke et al.'s [21] creative process categorization. Finke et al.'s [21] model is widely cited in studies on creativity and problem solving [13], [22]. Additionally, we included ranking solutions, as this frequently assists students to narrow down the scope of their ideation.

4 RESULTS

4.1 Explorative phase

A common exploratory strategy was exploration into similar solutions, using both visuals and videos, presented as a collage. These serve both as inspiration (on form and function) and as benchmarks to strive towards. Additionally, technical reviews were conducted to explore the limits and possibilities of various sensors or electronics platforms. The results from the technical review may be used to frame a brainstorm or result in the rejection of ideas. For example, team 10 rejected their initial concepts after realizing their technical complexity, and restarting ideation, limiting their scope.

Table 1. Overview of method used

	Explorative				Generative				Choosing
Team	Solution Ranking	Related Works	Technical review	Field research	Brainstorm	Scenario's	Sketching	Digital Images	Solution Ranking
1		X		X	X		X		
2	X				X			X	X
3	X	X			X		X		X
4					X	X	X		
5	X		X				X		X
6		X	X				X	X	
7	X	X			X		X		X
8		X	X		X		X	X	
9			X		X		X		
10		X		X	X	X			
11					X				
12		X		X					
13	X	X	X		X				X
14		X			X				
15	X			X	X		X		X

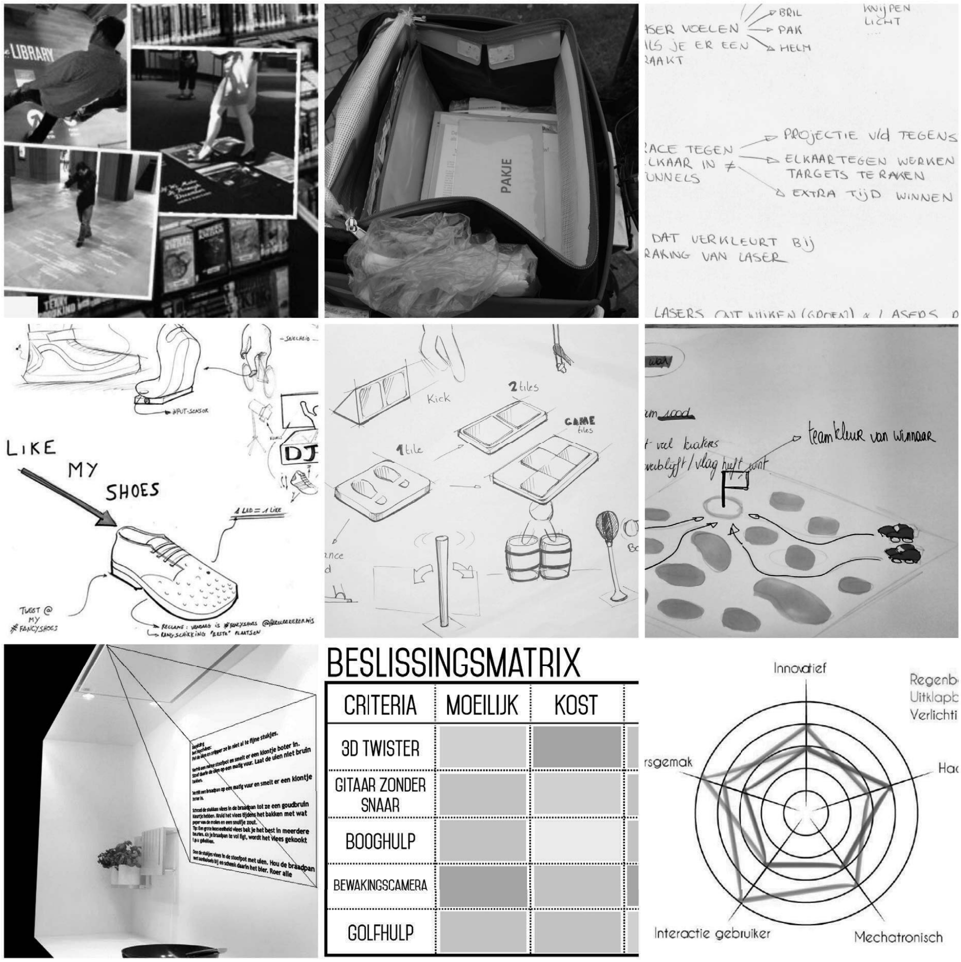

Figure 1. Overview of some of the ideation methods by students

In later phases not covered in this paper, students involved external stakeholders to test prototypes, but in the early phases external collaboration through field research was limited. An exception was team 15, who extensively involved their target audience (postmen) in their ideation phase, both through observational studies, interviews and film. Team 1, whose assignment was to make in interactive installation for a library, also performed research on location, while team 10 and 12 visited their client to better understand context of use, prior to ideation.

4.2 Generative

A common initial method for idea generation is a brainstorm, captured as mindmap. These brainstorms are loosely structured: they do not follow any script. Ideas are rapidly generated, or word associations written down. To narrow the scope of the brainstorm, students sometimes focus their efforts within particular themes. Later phases may see brainstorms narrowed down, by specifying particular criteria that new ideas must fulfil. Criteria may be derived from technical specifications or based on lecturer feedback.

Throughout this ideation process, students rely on sketches, most commonly after documentation of their textual brainstorm. They are limited to rough drawings, quickly drawn to work out a particular idea, while others could be more complex and include text to illustrate use scenarios. In later phases (week 4-5) digital representations were also made to show particular concepts in detail, including 3d renders, often as a way to communicate ideas to others.

Because the projects all involve a degree of interactivity, some teams created scenarios that capture typical use cases. Sketches are supplemented with stories and descriptions of task. They are a linear description of the interactions users may expect with the proposed system.

4.3 Overall process

While sketches, brainstorms, and looking for related works feature prominently in our review of used methods, they do not structurally occur in any particular order. For example, a brainstorm captured as a mindmap may be preceded by sketches and followed by a review of related products, after which a new cycle of ideation may start with the newly gathered information. Notably, students do not start first by questioning the initial assignment as presented by the briefing, but start generating ideas as almost as soon as the assignment is known. At most, they will request clarification on the briefing. In this review, we also include tools that allow students to narrow down their concept ideas. Typically, a list of criteria is developed (i.e.: fun, feasible, utility, cost), and concepts rated according to these criteria using radar plots or colour-coding. These efforts help the team to focus and provide a rationale behind rejecting certain concepts.

5 DISCUSSION AND FUTURE WORK

There are some limitations to this study. Firstly, it is not always possible to understand why a particular method was used. While the journals reveal various types of methods, students mostly refrain from expanding the reasoning behind the choice of a certain method. This study also does not show the effects these methods may have on final results. Additionally, the journals only indicate the various methods voluntarily reported by students in their journals and papers: they do not reveal methods implicitly used but not documented. Furthermore, it is not clear from this particular overview whether students benefited from the use of a specific method for their design problem, as opposed to another problem. Additionally, the reasons why students prefer one particular method remain unclear.

Most crucially, this overview shows that a very limited range of methods are used by students, with most staying with loosely structured brainstorms and sketches to illustrate ideas. This stands in contrast with the wide availability of ideation methods available in literature. Furthermore, students are reluctant to involve end-users in their early phase concepts. In one particular case (#15) students extensively involved end users, but found themselves struggling to implement their findings efficiently into their design. This study underscores what other authors have previously discussed: methods are only used in a limited fashion. Among the methods indexed, none are highly specialized or novel and are used in an unstructured way.

However, the fact that students have used these methods (conscious or not) and have documented it and posted it in their journal, illustrates that they found the outcome or the application valuable in their process. Even when results of a method show that the chosen direction was wrong and the query should be aborted, it may still be useful.

As previously shown (see for example [14]–[18]), certain ideation methods can result in better concepts. Given that some methods may be valuable to students, uptake of such methods remains low, how do students experience the use of methods as part of their design process? Furthermore, what is the rationale between rejecting particular methods in favour of others? Finally, if the use of certain methods are shown to be valuable, how can the use of these methods be facilitated?

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THE EFFECT OF PROFILING ON TEAM DYNAMICS AND CREATIVITY

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ABSTRACT
How do we, as educators, create and support effective teamwork with our students? This study focuses on the role of profiling tools. In particular we look at the use of such tools to create diverse, or heterogeneous, teams. We find that although there is a general preference for heterogeneous teams, there are other more powerful factors at play, including the nature of the task, familiarity of the participants, and cultural background. It is possible to have highly effective homogeneous teams given the right circumstances. Exploring further, we find that individuals in such teams consciously adapt their style to fit with the environment. Thus, equipping students with knowledge of their own (and others') profiles can be a valuable enabling factor in effective teamwork. We therefore suggest that profiling tools are useful as: a tool for self development; and a way of developing team work within a high trust culture.

Keywords: Group working, profiling, VIEW, Belbin, Hofstede, Profiling.

1 INTRODUCTION

Creativity is often portrayed as coming from an individual spark of genius. However, as Edison [4] and the Wright brothers [8] demonstrate, creativity in engineering design often arises from the team rather than the individual [11]. An important question for the educator is how to create, support and nurture these teams.

One principled approach is through the use of profiling tools. These tools suggest a set of behavioural preferences for each individual. The obvious questions that arise include: do these tools work; which is the best tool; should we create heterogeneous or homogeneous teams? The main focus of this paper is the latter question, including the importance of contextual factors.

The paper is structured as follows. In the next section we provide some background detail on the profiling tools used. We next describe the methodology, which is a mixture of quantitative and qualitative analysis. This is followed by a discussion and consideration of related work.

2 THE PROFILING TOOLS

VIEW™ [9] is a profiling tool concerned with preferred problem-solving styles and is credited with driving superior team performance [10]. VIEW™ characterizes problem solvers along 3 dimensions:

- **Orientation to Change** – Explorers "seek to break new ground" and "find structure confining". Developers on the other hand are comfortable with structure and focus on "organizing, synthesizing, refining and improving outcomes".
- **Manner of Processing** –when problem solving, people may adopt an External style, interacting with others and sharing information. The Internal style is more reflective and deliberative.
- **Ways of Deciding** – A Person-oriented decider is sensitive and preserves harmony. The Task-oriented decider is more concerned with logic and objective justification.

We also used Belbin styles [2] which include (mostly self explanatory) team roles such as: Coordinator; Implementer; Completer Finisher; Specialist. Plants are ideas generators; Resource Investigator the networkers; Shapers the salespeople. Monitor Evaluators provide a critical 'reality check' while Team Workers (an unfortunate name that downplays their significance) create and preserve team harmony.

Another key factor is that of cultural orientation. This is particularly pertinent for our cohort, which has 34 students spread across 14 nationalities. Hofstede [5] suggests a number of key cultural attitudes; the one we focus on is the Uncertainty Avoidance Index (UAI). Uncertainty avoiding cultures tend to minimise ambiguity by use of explicit rules.

3 METHODOLOGY

A cohort of MSc students were asked to work on four immersive design challenges, each using a different profiling approach. In each case the students were asked to fill in a survey appropriate to the profiling method being used. The responses were analysed by the course leader and used to allocate groups. The survey responses were not shared among students, although students were at liberty to reveal their profile to their team members if they so chose. In a few cases, due to absence or preference, students did not fill in a survey. Such students were allocated on a team size basis.

3.1 Challenge 1: 16-17 October 2014

The students were split into teams with a diversity of VIEW™ profiles and given a design exercise (involving the innovative use of cardboard) and allowed to organize their own time over a short (2 day) period with a presentation being required at the end of this time.

3.2 Challenge 2: 14-21 Nov 2014

The same cohort was split into teams with homogenous VIEW™ profiles and asked to contribute to a live project involving the innovative design of a baby incubator. The students were allowed to spend almost a week exclusively on this task. The assessment was a presentation and design brief given to the course leaders and the external innovator who had originated and was leading the project. The students were asked to write reflective logs on their experience during this 2nd challenge.

3.3 Challenge 3: 24-28 Nov 2014

The same cohort were asked to create a team presentation on a real product development challenge. This presentation needed to be prepared during the week, with limited free time being provided between and after lectures for group work. A simple cultural questionnaire based on Hofstede [6] uncertainty avoidance index[1] was used and the students were grouped into heterogeneous teams. The assessment was by presentation to the course leader and industrial guests who had set the challenges.

3.4 Challenge 4: 6-11 Feb 2015

The final group project involved the use of Belbin to create a well balanced team. The teams in this case worked on an immersive challenge concerned with organizational change. The teams had almost 3 working days (and a weekend) to work on this challenge. The assessment was a presentation to the course leaders and an invited industrial CEO, who role-played various actors in the given scenario.
In each case, quantitative results were collected.
A survey and a focus group were both conducted after all challenges had completed. The reflections gathered in the second exercise were analysed for comments relating to team work and the use of the profiling tools.

4 RESULTS

4.1 Quantitative Results

The cohort (34 students; one null response) had a bias towards Developer (Dev: 23/33), External (Ext: 27/33), and Task focused (23/33) preferences. Within this constraint, teams were allocated to maximise diversity. The effect on creativity appears muted; the marks were spread over a relatively narrow range (12%) with no obvious correlation between team profile and performance.
In Challenge 2 the teams were arranged homogeneously. In this case, the marks were spread over a wider range (25%) with a similar mean. The top team had some mixing of Developer and Explorer styles; on the other hand the next best team was completely homogeneous (all Explorer, External, Task).

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[1] See http://www.itapintl.com/tools/culture-in-the-workplace-questionnaire-cw/itapcwquestionnaire.html

The cultural questionnaires used on Challenge 3 gave rise to scores from -4 (uncertainty avoiding) to +7 (comfortable with uncertainty) and the teams were created using a balance of scores. The ranking is again over a fairly narrow range (13%). Finally, on Challenge 4 the students were arranged into heterogeneous groups using Belbin, with a mark range of 18%.

4.2 Survey

A survey was conducted in which students were asked a variety of simple questions on team working. 23 responses were received by 27 February 2015. Only 1 participant thought that team profiling was 'completely irrelevant' (and that person changed their mind after doing the challenges). On the other hand, only 1 person thought it would be the 'major determinant' with most ascribing a 'minor effect' (2) or 'important effect' (14) with 5 being not sure. Table 1 shows a noticeable preference for Belbin.

Table 1. Results of the survey. The table shows the responses to questions 2-4

	Useless and/or misleading	Not really useful	Somewhat useful	Very useful	Essential in team work situations	Other
2: What is your opinion of the VIEW tool?	2	4	14	1	1	1 (neutral)
3: What is your opinion of the Belbin tools?	0	1	12	8	2	0
4: What is your opinion of Cultural profiling?	0	6	7	8	2	0

Most students (14/23) preferred the heterogeneous VIEW work, with 7 preferring homogeneous and 2 declining to state a preference. Survey respondents were also invited to leave free text comments and some of these (with spelling and grammar left uncorrected) are noted in the next section.

4.3 Qualitative Findings

Reflective logs were collected in the 2nd challenge. In addition, a focus group was held on 16 February 2015. Thirteen students attended, and gave very useful feedback. In the following, various themes are explored backed up by comments from the focus group, survey or from the reflections. The comments are presented as they were received with no changes to grammar or spelling.

Students were generally positive, though they commented about the stability of profiles:

> *there might be some truth about VIEW profiling in the end.. [though] I still feel that the VIEW profiles are likely to change when you work with different groups*
>
> *I do trust Belbin but you can work in different roles*

Most people in the focus group (9/13) found the heterogeneous group easier. This was also true about the survey (9/13 respondents). It is interesting to look at the reasons why homogeneous groups are more difficult – or in some cases, easier:

> *In the second project, the group consisted of people with 'similar' mindsets and profiles. I felt a lot of disconnection and experienced conflict*
>
> *[with] different people/profile grouped together – they would create a conflict [in the] heterogeneous … easier in homogeneous.*
>
> *[when] group members are mostly from the same or similar categories, we either understand each other very quickly, or stick with one topic and very difficult to reach agreement.*

These comments suggest that profile diversity is not the overriding factor in team effectiveness. Digging a little deeper, it appears that successful team members can adapt to a new environment:

> *The 2nd one went better because I understood better how the other cultures behaved … I had [also] practiced team working*
>
> *This time I could not be as external as I could in the first group work (which probably was a problem) because my team members seemed to be as external or even more than me. This time I almost had to fight to be allowed to answer questions in our presentation whereas my last team seemed to encourage me to answer the questions for them.*
>
> *for the homogeneous, I was getting everything together – constructive discussion was already happening. For the heterogeneous – I tried to get some constructive conflict into the group. Difficult to say one was better.*

I think learning how to work in a team and being flexible with roles within the team might be more important or at least equally important as the composition of the team.

The last time I played the role of an explorer – this week I had to be the one organizing the team and getting them back to the right track

Thus, context appears to play a major role:

Other factors can also affect the performance in a group like culture and language.

I am not sticking to one tribe – I am changing…because of the environment — one year later [my] answer will change…

language make[s] me into another person - [I would have a] different result in China. (I think I am a coordinator not a shaper in China).

Introvert/extrovert - this is context dependent.– I am both.

behaviour is very context dependant. Even though I am a task focussed person according to VIEW I had a very person and emotion focussed approach this week and I am sure it is not just the topic but my ability to easily and naturally adapt to situations when necessary.

The students made some additional suggestions for the use of profiling tools, including

profiling tools should take into account the views of other colleagues.

Suggest doing profiling after a self select exercise.

5 DISCUSSION AND RELATED WORK

In the survey, most students (15/23) initially thought that team profiling would have at least an *important* effect, a suggestion that is echoed in the literature [8, 9]. Most students (both of focus group participants and survey respondents) preferred the heterogeneous teams, though a significant fraction had the reverse preference. It is also interesting that the range of marks is higher when the groups are homogeneous. This might suggest that the students had a greater diversity of experience with the homogeneous groups. Alternatively, it might reflect the nature of the task and/or the marking practice of the course leader. Of course, given the data it is impossible to do more than speculate whether the homogeneous VIEW™ profiles would have performed similarly in challenge 1. The qualitative findings are helpful in exploring this further.

These results are supported by the literature. Heterogeneous teams do appear to generate superior results [9], although a meta analysis [3] shows that this effect is both small and non significant, being outweighed by the context of the task. In addition, heterogeneous teams may be less co-operative at first [5] though this effect is transient. Even conflict within a team can be positive if it is creative rather than personal [7].

An important finding in this study is the importance of context; this factor appeared to greatly outweigh any advantage or disadvantage of profile matching within the team. This is also noted in the literature; for example problem characteristics appear to be highly pertinent [9, 7]. This later point is stressed in [1] in which the task environment (mechanistic or organic) directly affects the working style of the team. Examples of other relevant factors include

- The nature and difficulty of the task
- The familiarity of the participants
- The skills and experience of the participants
- The profile and personality of the participants (requiring an individual to adapt and take on a different role when necessary)
- Past success with a particular role (eg leader)
- The shared (or otherwise) language of the team
- The cultural background of the participants or task (eg tasks in different countries).

Perhaps the most significant finding is the transience of profiles (and therefore the adaptability of students). This does mean that any correlation between individual profile and performance is complex and arguably meaningless. However, the deeper finding is that the use of profiles enables students to learn about themselves, about others and about teams. The team challenges, when enriched with profile data, allow deeper reflection and experimentation with different behavioural styles.

It is therefore possible to discern a general acceptance of the usefulness of profiling tools. However, it must be acknowledged that the context has a major factor in determining how individuals behave within teams. Ironically, some of the contextual factors (particularly culture) are themselves measured by profiling tools. A suggested next step would be to make the profiling tools more open for the students to experiment with, to examine, critique and to share. Team members should be encouraged (not coerced) to share their preferred working styles and students should (individually and collectively) reflect on how these could be used to improve team performance. Further experiments (eg with different profiling tools, self select groups, peer feedback and so on) could be co-designed with the students. Finally, the role of context should form an integral part of any evaluation.

6 CONCLUSIONS

The findings suggest that profiling does not directly enhance the creativity of teams. Contextual and environmental factors are equally or more important. Nevertheless, knowing and reflecting on your own (and others') profiles can be a valuable enabling factor in effective teamwork.

We therefore suggest that profiling tools are useful

1. As a tool for self development
2. As a way of developing team work within a high trust culture.

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A RESEARCH BASED ON SIGNAGE DESIGN EXPERIMENT TO TEST USERS' ENGAGEMENT

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ABSTRACT
This research was based on the signage system design experiment in College of Design & Innovation (D&I), Tongji University. The new building of D&I undertaking a multi-functional complex for students and staffs was built and put into use in 2014, which appearing to be fertile for promoting communication, collective activities, fostering design thinking and triggering interaction between users and the environment. As part of the design for the new building, our team designed the signage system, looking at how to encourage users' interaction and engagement in the co design process. With the theoretical research, we choose the following methods to testify the users' interactive behaviour and feedback: VERBAL COMMUNICATION, ENVIRONMANTAL VISUAL STIMULUS and PEER EDUCATION.
This paper examines how those methods could improve in the users' engagement within the scope of a three-month prototype research. After the prototype and research process, relevant and informative statistics have been collected and analyzed.
The findings so far have led us to conclude that properly and purposed stimulus and the sequence of stimulus phases can lead to a more dynamic, effective, and innovative user engagement in co-design process. Further more, the methods can make big difference according to difference users. Appropriate methods for specific users could lead to effective results.

Keywords: User's engagement, interaction, participatory design.

1 INTRODUCTION

Three renovated buildings from auto garage form a multi-functional complex for D&I. To meet the functions and spirits of the environment (Figure 1), our team designed a new signage system, with the co-design thinking aimed to prompting interaction between users and the environment. We leave a "window" for users to finish on the template (Figure 2) to trigger interaction and invite users to accomplish the content. After the first prototype (36 doorplates), the barely few responses motivate the following research in reflecting design process with several stimulating and intervening methods sequentially.
Meanwhile, the signage system was developed gradually to improve the way finding experiences and help create the space to place. At the end of the whole research process, relevant design improvement was developed under the result of analysis and conclusion.

Figure 1. Interior space of the buildings

Figure 2. The new set of doorplates

2 AIMS

User engagement in this project refers to the many ways in which more individuals, in this context of a design college, students and teachers with design-learning background can be brought into the whole process of design and then creating further interaction.

The aims of this research are as follows:

1. How to improve the design prototype?
2. Test Pattern of design propelling and user response or interaction with the design prototype.
3. Reflections on implementation phase of participatory design.

3 THEORITICAL SUPPORT

3.1 Uncertain outcomes and risks of user engagement

However, engagement activity in fields of design may not always achieve expected outcomes. Given the possible situation, in the aim of breaking down the abstract concept of user engagement into something much more manageable, it is necessary to pre-consider the following aspects:

Designing engagement activities with a particular outcome in mind, however still including an extra or additional benefit as a by-product of the process.

- For designers, new perspectives on and a better understanding of specific challenges, together with more appropriate and better targeted programs and responses will be attained, and access to a greater diversity of ideas will benefit design activity.
- For users, increased confidence and skills, along with new and stronger networks will be created.

There are few clear links between the practice of participation and the benefits it is supposed to deliver. And tracking the impact of participation is challenging because many of its goals, like 'capacity of creativity' or 'cohesion' - are often ill-defined and therefore difficult to measure or quantify. [1]

Risks of failure in terms of engagement activities needed to be taken into consideration include self-exclusion that not everyone wants to take part in participatory processes and that poorly practiced forms or negative experiences of engagement can also rise the risk of disengagement. [2]

In general, a set of key notes is supposed to be thoroughly considered before engagement[4]:

- Defining engagement activity explicitly with consideration of the context in which it operates.
- Select the appropriate group of users for engagement, through considering quality of interaction, methods of participation stimulus and taking account of barriers to engagement.
- Tolerating a certain amount of uncertainty outcomes – both positive and negative.

4 METHODS

4.1 Verbal communication with users

In participatory design situations, conversational behaviour of the facilitator and the way in which a project is introduced and explained verbally tend to have impact on users' engagement. Design occurs in conversation. [3]

A seamless expert conversation, consisting of relevance to users' lives thus prompting a positive engagement in the discussion of the subject. Verbally modifying and evaluating the merit of different design arrangements. Users become more engaged in the workshop, may even suggest alternative approaches to rationalize designs.

4.2 Environmental visual stimulus

Research in cognitive psychology and in design thinking has shown that the generation of inner representations in imagery and external representations via sketching are instrumental in design problem solving [5]. Architectural design patterns were specifically designed to give non-professionals the power to create good design [6]. Thus, the D&I college buildings, a renovation project, can spare space for innovation. Designers think visually, thus, external visual representation in design present in the designer's working environment can be regarded as stimuli or prompts as strong cognitive resources. Accidental features of the environment or random encounters with external stimuli might direct problem solving in a particular direction. Creating conditions with cues suggesting useful that can potentially motivate the most effective design performance may benefit user engagement greatly.

4.3 Cases as forms of facilitation

Designer as facilitator ought to enable collaboration between diverse users within the design process. Forms of facilitation within the co-design work as a 'design device' affording certain functions that opens up 'new ways of thinking and behaving', aiming to deliver public and collaborative services.

Representative case references proves to be educational in improving independent thinking and analysis, as well as capability of solving problems, thus creating reproduced knowledge or active knowledge.

4.4 Peer education & implantation of mobile media

D&I college buildings appear to be fertile for promoting opportunities for dialogue, collective activities, and mentorship among peers from all disciplines or different grades .In comparison to those weaker in designing, students with advanced experience will enthusiastically engage in, and will soon dominate by enabling themselves to provide significant peer-to-peer support. [7]

Nowadays, implantation of social mobile media increases the viscosity of social audience and fostering the spread of information. Social mobile media are involved into design process especially among young students due to its popularity and educational or directive influence.

5 RESEARCH

In the design process of this set of doorplates, we leave one segment to users through leaving clues on the template(Figure 3). In addition to engaging users into finishing the whole design, we conceive of promoting this interaction at a better level.

Figure 3. Prototype of the doorplate

5.1 First-phase research

After the first-phase design—36 doorplates were installed. Within two weeks, only two of thirty-five doorplates were actually "used".

The feedback turned out that some of the users found it difficult to get the exact clue, others described their doubt of the doorplate function. As a result, we need to figure out the reasons for the lack of participatory action, as well as further research methods to "nudge" highly engagement from the user.

5.2 Second-phase research

Three steps are used to test the effects of design propelling methods to increase users' engagement.

1) Verbal communication--Explain the erasable material of the doorplate, and demonstrate the special design purpose.

We choose two groups of users, the administrative staffs and undergraduate students, to give verbal communication separately. Users gave some immediate feedback of the functions and questions on the interaction content through this "window". Two of the former group of users are appealing to functions, and they give response instantly with some simple information, such as working hours. Some of the latter groups are more interested in our design intention, and they draw some graphic patterns along with unique information such as slogans.

At the end of this step, two of these three tested administrative offices participated in the interaction part by showing useful office information. At the meantime, two of six tested classrooms have their own design of the doorplates showing unique characteristics. During this step, conversational skills are important in aiding users to better understand the intention, which was interpreted as applying accomplished facilitation skills of encouragement.

2) Case reference——Engage users into creating several case as reference for others.

We invited several design-based students from two classrooms, who had nothing in response to the first step, to participate in this case reference workshop. These students got instructions of the intention of the doorplate design (Figure 4). They separated into two groups, each for one classroom, discussing class spirits and their attitudes to design. Afterward, they put information like "Multi funny guys—home for class three" onto the doorplate decorated by using different fonts and colours.

The next day, the doorplates of two other classrooms in the same presented new appearance with some humorous information (Figure 5). One of the doorplates got a bilingual instruction of how to use the classroom with friendly sketches.

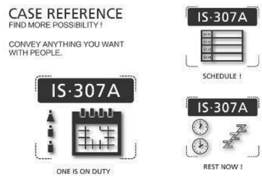

Figure 4. cases references

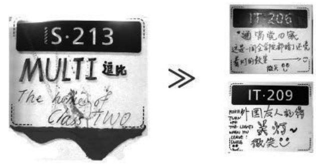

Figure 5. Users' interactive cases

3) Instruction——Put up a poster as instruction.

Based on the responses we have got from the former interaction with users, problems have been raised and can be analyzed into five questions—what the doorplate is for, who are actually going to use, how to participate in co-design, what will happen to it when finished, how to keep and promote it. We finally used the format of a poster to demonstrate the whole "journey" of the doorplate design, combining both literal and graphic information in this visual instruction with the configuration of co-design (Figure 6).

Figure 6. Instruction poster Figure 7. Three sites are chosen to display the posters

We deliberated the precise sites to display these posters, which are uniformly distributed in the space to reach as many people as possible (Figure 7). Been observed for one week, we find out the bulletin board and column tend to be much appealing to people for stop and stare.

Some of users responded with deeper understanding and interest in the interaction process. However, some negative opinion emerged complaining that this instruction is somehow complicated to follow. Furthermore, some users are intrigued but confused about the promotion and competition of their co-design process. As a result, we are seeking for appropriate solutions of promotion.

5.3 Third-phase research

Finished conducting the above research phases, from which engagement and responses are acquired, we turned to focus on digital interaction and impacts of social media.

1) Disseminating information through public social media

Digital version of the instruction poster, together with an encouraging brief description document, is posted as an activity news onto the college website of D&I. Shortly afterwards, the poster and the document are distributed via two other popular social media, QQ group (an online public chatting platform) and WECHAT. These two media play important role in disseminating information especially among young students.

2) Rewarding and promoting design participation through public display

We record the test result and grade the output of users with three levels: A—functional/identification information, B—entertainment information, C—both functional/ identification and entertainment information. For the next phase, they will be uploaded onto website or spread via social media for voting. We hold the hypothesis that designing competition within groups of users and wider engagement of audience should bring more positive participatory activities and create a more dynamic atmosphere of designing communication and innovation (Figure 8).

Figure 8. Ways to encourage better interaction and to create atmosphere of innovative design

6 DATA AND FINDINGS

6.1 Statistical data

After the whole design and research process, we analyzed the statistical data in the sequence of research steps, and compared the data collected from different users (Figure 9).

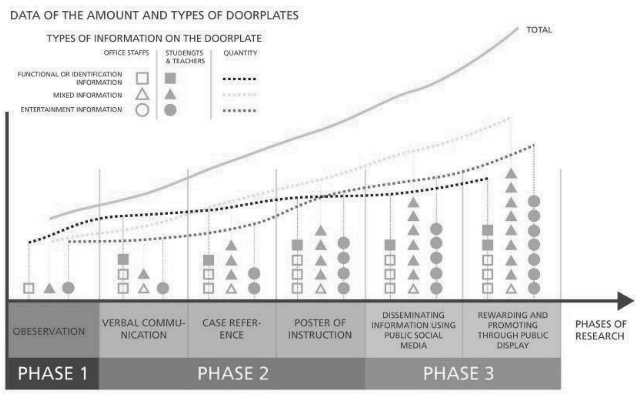

Figure 9. Chart of data collected from users in the sequence of research steps.

As can be seen from the chart, doorplates of rooms for teachers and students with design education background far outnumbered those of office staffs. Meanwhile, the number of doorplates co-designed by students or teachers showed a trend of sharp increase while that of those co-designed by staffs rise smoothly.

From this chart, the magnitude of the increase revealed a trend of fluctuations in different steps of research. In detail, user engagement increased steadily under the steps of verbal interaction and disseminating information using public social media, however, under the steps of case reference and poster of instruction, as well as rewarding and promoting design participation through public display, users' engagement was proved to undergo a comparatively sharp increase.

A much higher proportion of entertainment and mixed information (totally 15) than functional information(totally 2) in context of doorplates co-designed by students or teachers while functional information took up a larger proportion in terms of doorplates co-designed by staffs.

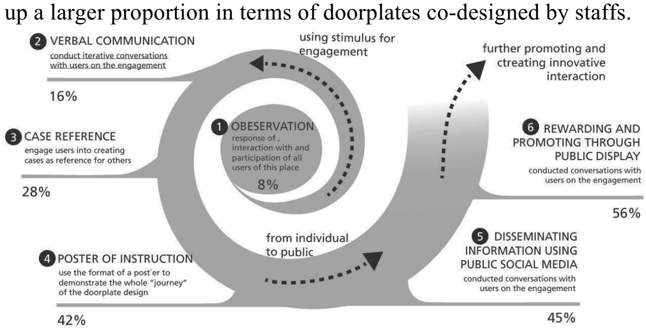

Figure 10. Chart of data collected from users in the sequence of research steps

In the diagram (Figure 10), the relationship among the whole three research phases and the sequence of each step are clearly revealed. In detail, user engagement increased as the steps executed gradually, among which we witnessed the highest increase rate in the second phase with three different stimuli for promoting better participatory actions.

As can be concluded from the diagram (Figure 11), environmental stimulus and peer education, as theories, actually has great impact on all the methods we used in the user participatory action research. Meanwhile, implantation of mobile media plays an increasingly significant role in triggering and promoting user actions.

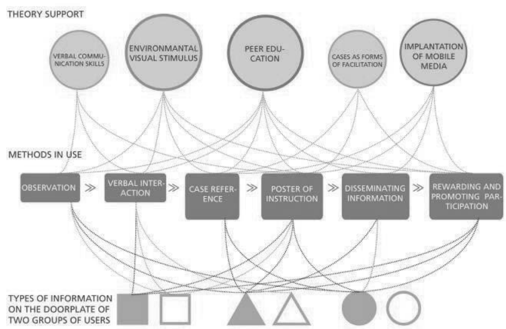

Figure 11. Connections and relationship patterns

Figure 12. Improvement of the design

7 CONCLUSION

With the context of a design college, this research has helped to induce and analyze students' cognitive behaviour in design. In addition, design research based on real project inside learning environment can actually have impact on students' behaviour and design thinking and can be cases for teaching and learning.

The research of user engagement in co-design process is still in progress. The research , data and findings set out in this paper have led us to conclude that properly and purposed research stimulus and the sequence of research phase can lead to a more dynamic, effective, and innovative user engagement in co-design process.

Statistics have shown that the differences between participatory actions of two different user groups in this research actually have profound impact on final result. Due to less attention to behaviour and thinking patterns of the people without design background, only a few useful responses are eventually collected from this group of users. In the process, peer education is helpful for almost all the phases, which can be a positive reference for future research involving user interaction.

Thus, the methods can make big difference according to difference users. Appropriate methods for specific users could lead to effective results. With this result, the design was improved after the three research phases according to different users (Figure 12).

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Chapter 20

Technology and Knowledge Transfer

AUGMENTED REALITY FOR ENHANCED STUDENT INDUSTRIAL DESIGN PRESENTATIONS

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ABSTRACT
Augmented reality (AR) has developed rapidly in recent years, causing the technology to move out of the preserve of large budgets and significant infrastructure, into an accessible and affordable visualization tool capable of running on a smart phone. However, the usage of this technology for superimposing digital content such as 3D models and images onto the real world, has not been sufficiently explored in industrial and engineering design for presentation purposes. Even though designers have access to various tools and methods for presenting design projects, some of which are digital, intended user experiences or product specifications are sometimes not conveyed satisfactorily. This paper explores the potential of AR technologies to enable designers to enhance their 2D presentation boards and 3D physical mock-ups with an additional layer of digital information. The study was carried out in an educational context through a design project (bedside alarm clock) with eight postgraduate students. Students were exposed to three project parts: 1) AR presentation and software demonstrations; 2) concept design and creation of AR content; and 3) evaluation of utilized AR software. Digitally-created design content was successfully presented interchangeably and overlapping in real-time with physical media. The experience was variously described as presentation boards and mock-ups 'coming to life' with augmented content including text, images, animations, video and sound. The latter was found especially valuable for properly conveying the audible design intent for the alarm clock projects. The paper concludes on how AR technologies can support industrial design presentations and some suggestions for technological developments.

Keywords: Augmented reality, design presentations, industrial design, visualization.

1 INTRODUCTION

Augmented Reality (AR) is a way of superimposing information generated by a computer into a real environment [1]. In other words, AR is a vessel to incorporate computer-generated data within real space, combining real and virtual objects with each other in real-time [2]. According to Milgram et al. [3], AR is situated in a continuum of mixed reality, between the real environment in which humans exist, and a completely virtual environment comprised only from digital data. For a system to be described as AR, it needs to be combined of real and virtual elements, be interactive in real-time, and be observable in three dimensions [4].

AR is made possible through a combination of hardware (e.g. computers or mobile devices, cameras, projectors, monitors, trackers/markers) and software (e.g. apps or programs, web services, content servers). The technology has uses in a wide array of commercial and research fields. In the commercial field, sectors such as advertising, architecture and construction, museums and tourism, medicine, mechanics and repair, social networking, entertainment, military, and navigation have made use of AR. Recently, research and development examples of AR have also gained public attention, with the AR head-mounted display Google Glass (developed by Google X) being one of the most widely known.

Until recently, AR was the preserve of large budgets and significant infrastructure. In the intervening time, AR has become accessible and affordable, such that AR applications can now run on smart phones, and are able to display digital content such as 3D models and animations onto 'augmentable' surfaces. There has been research on the uses of AR in industrial design activities, including: visualization of products, usage simulations and ergonomic analysis [5]; virtual design environments, augmented prototyping, and industrial design assembly [6]; and collaboration across design disciplines

[7],[8]. One underexplored area where AR has potential benefit is during formal design communications in industrial and engineering design. Throughout their education, industrial design students are expected to present the progress of their design development with a variety of visualization tools. Although designers generate highly convincing photorealistic renderings or simulations of product proposals, it can be argued that in some circumstances intended user experience or product specifications are still unsatisfactorily conveyed. In other words, presentation boards and mock-ups are sometimes not adequate to show interaction details of a proposed product such as audiovisual feedback. At the current state of the technology, there are various ways that AR could supplement the presentation of a product. Accordingly, this paper reports on a study to explore the potential of AR technologies to beneficially provide an additional interactive digital layer of information onto 2D presentation models and 3D physical mock-ups, typical of the deliverables of an industrial designer.

2 THE FIELDWORK

The study was carried out in an educational context through a design project ('bedside alarm clock') with postgraduate students. This provided an ideal setting for experimentation and feedback, whilst being sufficiently close to professional practice to judge commercial applicability.

2.1 Selection of Participants

Eight graduate level industrial design students, taking 'ID 535 Design for Interaction' course at Middle East Technical University, Turkey during 2013-14 Fall semester, participated in the study. All of the participants had design and modelling skills expected from a postgraduate-level student, and all had a mobile digital device (e.g. smartphone or tablet) which was necessary for their participation.

2.2 Selection of AR Software

Several software/apps developed for AR content creation and management including Layar, Daqri and Metaio were reviewed by the authors. Among these, Metaio [9] – available on Android and iOS platforms – was selected, because it enabled users to create their own content and display content through channels that they publish. It was also available as a well-specified freely downloadable version (as well as more advanced paid subscriptions), providing relatively wide opportunities for creating and publishing content compared with the other reviewed apps. Metaio software consists of two interconnected parts serving different purposes. 'Metaio Creator' is used to upload digitally created content and link that content to markers, which eventually become published into channels. 'Junaio Browser' is an application used to scan markers and thus to connect to the channels published with Metaio Creator and view AR content. The types of data that Metaio Creator can augment onto the real world ranges from 3D models to 2D images, sound files, etc.

2.3 Stages of the Fieldwork

Students were exposed to three project parts: 1) AR presentation and software demonstration; 2) concept design and creation of AR content; and 3) evaluation of utilized AR software. The design project ran for five weeks, during which time the authors made themselves available to each participant through a feedback session, essentially acting as a 'drop in' to answer questions and offer advice about how to exploit the capabilities of the apps.

2.3.1 Part 1: AR presentation and software demonstration

In part 1, the participants were familiarized with the mobile AR app (*Metaio Creator*). The basic structure and a short tutorial of the app were shown, along with example uses showcasing the capabilities of the app through design projects that the authors have implemented.

2.3.2 Part 2: Concept design project and adding interactive AR content

In part 2, the participants were asked to make use of Metaio Creator to add an interactive content layer to their final (2D) presentation boards and/or their final physical (3D) mock-up of the concept bedside alarm clocks they had been working on. At the final presentation, the participants presented their interactive content on their presentation boards and 3D mock-ups. The AR layer of each presentation was documented with photographs and screenshots.

2.3.3 Part 3: Evaluation of Metaio AR app

In part 3, immediately after their presentation, the participants were asked to complete a survey evaluating their 'likes and dislikes' of the app, alongside an appraisal of how the use of the app had brought about enhancements in design communication. Participants were also asked about extra features that they would like to see added in such an app (not necessarily as enhancements to Metaio Creator), and whether they would be enthusiastic to use AR technology in subsequent projects.

3 RESULTS AND ANALYSIS OF THE FIELDWORK

As can be seen in Table 1, during the final presentation of the bedside alarm clock project, all of the participants had *sound* augmented in their presentation boards. The sound of the alarm was either embedded in a video that showed detailed interaction steps during usage, or activated separately to demonstrate the sound choice for the alarm. The videos were augmented both on the presentation boards and mock-ups. For the presentation boards, most (six) of the participants showed the alarm lights and movements of the product in their videos (Figure 1), whereas a few (three) of the participants showed the interaction steps, be it the screens in the digital interface (Figure 2), or the tangible interaction details. One of the participants chose to show the alarm light glowing, and another participant decided to present the interaction steps of the digital interface in the form of a video on top of the surfaces of the physical mock-up. One participant took it a step further by augmenting a very simple mock-up of the project with a more detailed 3D model, showing qualities of form, material, texture and graphics chosen for the product (Figure 3).

Table 1. Additional AR content in the 'bedside alarm clock' project presentations

AR content	Purpose	Number of participants integrated (out of 8)	Medium of presentation
Sound	alarm	8	2D presentation board
Video	alarm lights and the alarm-clock's movement	6	
	interaction steps	3	
	alarm lights	1	3D mock-up
	interaction steps	1	
3D Model	product form, material texture, graphics	1	

Figure 1. A participant scans the markers on the presentation board (left) then the mock-up (right) to demonstrate the augmented animation of the glowing lights on the alarm clock

Figure 2. A participant shows interaction details through a video located on the mock-up

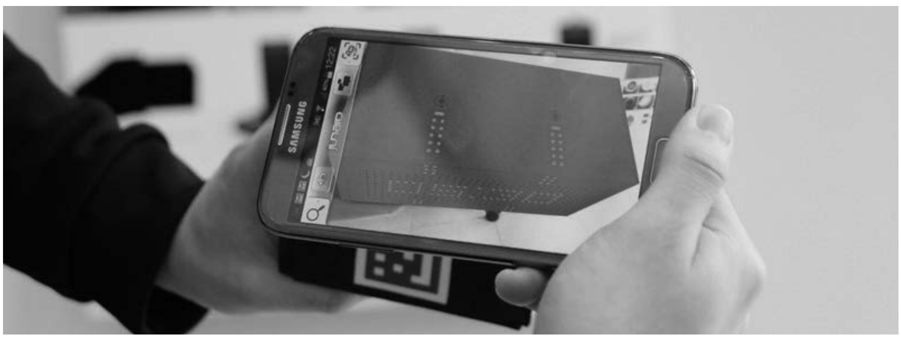

Figure 3. A participant scans the marker on a primitive mock-up to reveal a more detailed 3D model of their intended design

3.1 Using Metaio in a student design project

The participants showed great success in using the AR software package Metaio to enhance their design project presentations. They were able to show the usage scenario and digital interface details from start to finish with audio-visual feedback. Having easy access to an AR app to show digitally created content that explained user-product interaction steps in real-time was an impressive advantage over using static 2D presentation boards. If they had not used AR, the only other way that participants could have shown product operation and sound feedback would have been by using a laptop or computer screen next to their presentation boards, and manually showing the relevant data during the presentation. However, this would not have been possible in a setting where the designer was not present next to his/her presentation board, such as an exhibition. By placing markers on presentation boards, designers allow every viewer with a mobile device to see extra content that can help explain the interaction details of their product proposals.

One particularly inspiring and effective use of AR for student design presentations was demonstrated by enhancements to physical mock-ups. Participants were able to augment videos showing digital interfaces, dynamic details and texture properties that would be either impossible or very time-consuming to create and physically model within the scope of an educational project. The most significant and perhaps revolutionary advantage of this was the way that augmented data was correctly located onto the mock-up, and furthermore able to be rotated within 3D space yet still remain correctly located.

3.2 Feedback on the use of Metaio

Very positive reactions were received from the AR-enhanced presentations, both from the audience (design tutors) and the student participants themselves. The participants found the Metaio software package easy to use, and that the abundance of useful attributes and its free-of-charge availability justified its learning curve. Participants thought that with AR, their presentation boards were much more fun and interesting, while they were able to present information about their product proposals to a greater depth. The adjectives that the participants used to describe using AR in their presentations were: surprising, informing, fun, interesting, attractive, and even magical. They were able to present everything that they would have liked to present about the interactive elements of their designs through the functionality offered by Metaio. It was considered an 'eye-opening experience', which would encourage participants to use AR apps in communicating their future design projects.

The participants also had some negative comments about the AR implementation process. Some technical problems related to the software seemed to be a setback, albeit a minor one. For example, the size of the marker and the lighting conditions were found to affect the smoothness of tracking. Glitches in the interface of the content creation software made it difficult at times for the participants to edit digital content within the app. Perhaps the most noteworthy disadvantage of the software was that it was not specifically tailored to suit to the designer's workflow. However, these disadvantages did not diminish the potential that participants regarded for the implementation of AR within their project presentations, but nevertheless could provide a basis for improvement criteria for AR software or apps targeted specifically for use by industrial designers. These criteria are listed below.

- Ability to track more than one object; being able to interact with multiple objects at the same time; having object-to-object interaction as well. This would mean that product concepts with more than one component that are linked together in some way could be prototyped.
- Ability to edit digital content on the viewing mobile device, rather than a separate PC, would improve the workflow with regard to content creation and evaluation, prior to finalization.
- Use of video projection to display AR content directly on top of a presentation board or 3D mock-up, as an alternative to viewing through the display of a mobile device. This could provide a more intuitive and convenient way of experiencing the AR content.
- Integration with a head mounted display (such as Google Glass) could provide even more convenient ways of experiencing the AR content on augmented presentation boards and 3D mock-ups.

4 CONCLUSIONS

The work presented in this paper focused on using the mobile AR app 'Metaio' in a bedside alarm clock industrial design project, to enhance students' presentations of interactive and multimedia product details such as sound, visual elements and feedback, and digital interfaces. The study resulted in some remarkable AR content, found to be novel, inspirational and captivating to all involved: students, tutors and guests. Digitally-created design content was successfully presented interchangeably and overlapping in real-time with physical media. Student designers had success with Metaio in presenting such details on their presentation boards and mock-ups. They were able to show videos of alarm lights and movements, the interaction steps, the texture and form of intended designs as a 3D model overlay, and the audible sound of the alarm clock. By creating this additional layer of information on their presentation boards and mock-ups, participants were able to show details of their projects that would not have been possible to show with traditional presentation methods. It was promising that the quality of their presentation was heightened considerably and none of the participants had crucial difficulties during the process. Their ideas about improving the whole experience of using AR to enrich presentation will be useful for further studies on the subject.

Industrial design students were able to present their product and interaction ideas in a much more attention-grabbing way than traditional methods. Because AR was a fun and interesting way of enhancing their presentations, student participants exhibited much confidence during their final presentations. Creating additional digital content to overlay on their presentation boards and mock-ups made them think about the details of their projects in more detail. Additionally, a major achievement from enhancing mock-ups was that even a simple model with very little detail could be turned into an elaborate prototype with lights, sound and digital interfaces. A prototype that shows these details would be very time consuming and difficult to realize in an educational context. However, with AR it was possible to achieve in a short time span with minimal effort.

The principal conclusion, shown through the work of the students, is that in (industrial) design education the utilization of AR for presentation purposes can undoubtedly help students portray their ideas in a more detailed and interesting way. To utilize AR in long-term (e.g. semester length) educational design projects, the view of the authors is that it is essential to (i) introduce students to the technology during the briefing stage of the project through a thorough and effective presentation of possibilities and examples, and (ii) provide students with close (product-specific) guidance to support their implementation of AR throughout their project progression.

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EXPERIENCES OF EMBEDDING BLENDED PHYSICAL AND DIGITAL MAKING INTO DESIGN EDUCATION

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ABSTRACT
This paper considers modern concerns that a new generation of designers are rejecting traditional methods in favour of purely digital ways of designing. The study is contextualized in some of the relevant theory, and describes a selection of projects across academic levels from the design curriculum at the authors' institution that illustrate a blended approach to digital and physical design pedagogy. Results are presented from a survey of final year students who have experienced this approach, exploring the extent to which these methods are now embedded within their practice. The results suggest that although CAD use is prevalent in their natural practice, and some of the recognized problems associated with it are more evident than in professional CAD users, the students have adopted our approach of designing across digital and physical platforms.

Keywords: Digital, physical, designing, making, blended learning.

1 INTRODUCTION

The toolkit of methods by which ideas may be explored, represented and developed has never been more extensive for designers, supported particularly in recent years by seductive digital manufacturing techniques such as 3D printing. Whilst this technology has existed for almost as long as the CAD systems that drive it, it has gained significant cultural currency in recent years, since the expiry of certain patents engendered an explosion of affordable desktop machines, democratizing the technology to a level never before seen. In design education, both prior to and at University level, this trend, coupled with the prevalence of CAD and photorealistic screen-based visualizations has shifted the gamut of making skills to the digital arena. Jonathan Ive, in an interview at the Design Museum in 2014, highlighted this erosion of making and craft skills from design curricula as 'tragic' [1]; David Kelley of IDEO describes prototyping as "thinking with your hands" [2] – which carries an implicit sense of the physical and craft based techniques that are absent from purely digital design work. Richard Sennett describes how "CAD is often used to hide [problems]… it can be used to repress difficulty" [3]. Mindfulness of these concerns, supported by observation of student practice, has guided the design of teaching methods and coursework projects for undergraduate design and engineering design students at London South Bank University (LSBU). The objective of a new curriculum model, introduced in 2011, was to embed an integrated approach to design that embraces, wherever possible, the appropriate use of both digital and analogue modes of working, limiting effects of "circumscribed thinking and bounded ideation" [4] and reinforcing immediacy, reflection on process and 'fit' of the product outcome.

2 CAD AS A TOOL FOR CREATIVE DESIGN?

In order for a representation of a design concept to be given tangible form through digital manufacture, it must first be described explicitly in CAD; 3D printing provides a physical embodiment of the digital model, and thus the software packages become the gateways to the tools of digital making. The implications and limitations of the use of CAD in creative design have been the subject of extensive discourse for at least two decades, a full review of which is beyond the scope of this paper. It is well established that as a tool for engineering, and for detailed, precise development, visualisation and communication of mature design ideas, CAD augments human capabilities hugely. It seems though, that CAD has been incorporated into the practice of design as swiftly as the technology, the hardware, and the interfaces have been developed, with little pause for consideration of the impact on creativity and the traditional design process flow.

Computer systems inherently require precise and explicit input from the user. Modes of input and interaction in CAD have now evolved from what began as digital simulations of established 'classical' practice, the use of drawing boards for orthographic projection drawing. Some of the mechanisms by which CAD can limit creative design ideation were recently re-examined by Robertson and Radcliffe [4]. They describe 'circumscribed thinking' (the system constrains the thinking of the designer through limitations in representational capabilities or the skill level of the user), 'bounded ideation' (the adverse motivational effects on creativity that result from negative or frustrating experiences using the software), and 'premature fixation' (how the complexity of a CAD model as it evolves disincentivises the designer from making fundamental, topological changes to the design).

This is in stark contrast to the typical ways that designers work at the front end of a project, the ideation or creative stage. When sketching ideas with a pencil, designers embrace ambiguity, abstraction, and imprecision in order to facilitate an experimental creative flow of ideas. The specific, precise input required by computers – in particular, parametric modelling systems - is inherently contradictory to this creative flow by "distancing the designer from the cognitive thought of creation" [5]. Other authors such as Bermudez and King have shown that manual representations are more appropriate at the conceptual design phase [6]. They predicted, even at that relatively embryonic phase of digital adoption, "not the extinction of the analogue in the hands of the digital but rather a coordinated and collaborative coexistence of both representational systems". Oxman considers whether "digital design is a unique phenomenon – a new form of design – rather than merely conventional design accomplished with new media", and suggests that "digital design and it's growing impact on design and production practices are suggesting a need for a re-examination of theories and methodologies in order to explain and guide future research and development" [7]. We accept, therefore, that these discussions are by no means novel, but in this paper, we reconsider them in the light of the modern ubiquity of digital content creation and manufacturing tools, and the question of whether an emergent class of 'Digerati', or 'digital *literati*' [7] are rejecting traditional, analogue making skills for models produced solely through digital means.

3 BLENDING PHYSICAL AND DIGITAL MAKING IN DESIGN EDUCATION

A module restructuring exercise offered the opportunity to revise the delivery of design courses at LSBU; the guiding objective was to embed blended approaches to digital and physical making through practice-based coursework projects. A structure was developed that placed Design Thinking and Practice as the central core module (50% of the available credits for each academic year), into which skills were fed through supporting modules. This teaching model aimed to foster an appropriate balance between digital and physical design methods; we believe that bringing the data set out of the computer and onto the workbench provokes ideation through the immediacy of manipulating physical materials, and the opportunity to react in real time and space; the likelihood of physical spatial inconsistencies brings serendipitous possibilities for novelty; and collaboration is fostered through the ability to interact over the tangible representation. The following sections will describe some of the projects from our curriculum that illustrate this approach.

4 LEVEL 4: AN INTRODUCTION TO THE 'PHYSICAL/ DIGITAL' BALANCE

At level 4, the core content is fundamental cognitive design skills involving creativity techniques, concept development, and user empathy. These are supported with a strong toolkit of practical skills that include design sketching, physical making, graphical (digital) communications, and CAD, alongside discipline (and course-) specific specialisms such as applied engineering maths and physics or social sciences such as ethnography.

The 'Pen Project' provides a vehicle for the introductory CAD course. Assuming no prior experience of digital design, students are taught the principles of solid modelling through bespoke video tutorials, inspired by the Khan Academy [8] model of teaching mathematics. Students must design a pen from a billet of aluminium tube, with separate components for an end cap and a nib detail, and housing an off-the-shelf refill cartridge. The accompanying lecture course covers the capabilities of manual lathes and milling machines, and then focuses on conventions of engineering drawing. Students submit a set of engineering component and assembly drawings, derived from a 3D solid assembly; the components must show evidence of both milled and turned features. The following semester, in another module, the students are taught how manufacture their pens in an engineering workshop, working from the previously submitted drawings. Content includes the practical and safety aspects of using the associated machinery, and empathy for the tools of production. The intention is that when students work from drawings they have produced themselves, missing dimensions, or overly complicated details require mental leaps and decisions to be made on the workshop floor – decisions which are only possible if the designer is also the maker. The drawings become vehicles for verified dimensions and occasionally drastic design changes, losing the veneer of permanence, as they become tools for iteration. The final work pieces are often the result of a combination of happy accidents, developments bought about by compromise or radical departures from the original intent following enlightenment through physical manipulation of machine, material and process. This workflow direction, from digital to analogue, was specifically chosen in order to highlight the problems that can arise from purely digital designs.

The 'Electric Vehicle Challenge' provides a second explicit example of blended physical and digital designing at level 4. Students are provided with a small electric motor and gearbox kit, including axles and laser cut wheels. They are required to assemble these, explore gear ratios, mount them to a chassis and design an external surface shell, initially by modelling in foam and subsequently vacuum formed in HIPS. The vehicles are raced head to head at the end of the semester down a 20 metre track; each must carry a 'passenger' in the form of a 30 gram (rubber) egg. The motors are exaggeratedly underpowered for the mass of the assembly; in order to be competitive against their peers, a high level of craftsmanship is required in the construction, assembly, and alignment of the components. Students are taught about gear ratios, basic electronics, principles of aerodynamics and styling, and the use of jigs and other devices for precision manufacture and assembly. Concurrently to the physical assembly process, in the CAD module students are tasked to reverse engineer all of the core vehicle components using parametric software to create a virtual assembly. They explore product architecture digitally by creating multiple configurations of the components to select an optimum design. The chassis design is derived from the configuration of components, and the profile is output for laser cutting. When complete, the solid assembly is imported into surface modelling software, where simple organic curves are drawn around it to derive the external shell surface – providing an introduction to the principles of surface modelling in CAD.

5 LEVEL 5: EXPERIMENTS ON MICE

'Experiments on Mice' is a coursework project at level 5 that builds on these skills, introducing more complex techniques in surface modelling, in detailed design development with solid modelling packages, and in output to digital prototyping and manufacturing systems including 3D printers and laser cutters. The students are tasked to design computer mice. The mouse was chosen for a number of reasons: it is an intrinsically ergonomic object that requires physical modelling to ensure a comfortable fit to the hand in use; it is of a size that allows cost effective 3d printing for a class of approximately 50 students; the core components can be bought cheaply for reverse engineering and assembly into the models (both physical and digital); and it requires at least two plastic components that fit closely together and are typically injection moulded, with all of the associated design detailing required. The project is initiated with approximately 8 hours spent in a prototyping workshop, during which the students use sketching, and physical model making in foam (subtractive) and plasticine (additive) to define a range of optimal forms, one of which is selected to begin digital modelling. From that point, models can be 3D scanned, importing the scanned mesh to surface modelling software. Those that 3D scan must use the mesh data as an underlay over which to build a native CAD surface model from original curves. The physical models are used to sketch control curves onto in order to plan the surface modelling strategy. Once the external surfaces are built, students are encouraged to produce physical 'reality check' models to confirm scale and ergonomics. In order to save the material costs of 3D printing at this stage, and to emphasize speed and efficiency in the use of model making, their models are produced using planar sections, laser cut in 5mm foam. This ability to quickly evaluate the low fidelity models in tangible form frequently results in further design iterations (through manual reshaping of the foam), again reinforcing to students the need to treat purely digital representations with caution. Once surfaces are finalised, they are imported to solid modelling software in order to split the components, and apply thin walls, ribs, bosses, draft angles, lips, and all of the other associated features of injection moulded components. This emphasizes 'good housekeeping' on the surface model – if surfaces are not properly stitched or accurately trimmed, it will not translate easily to a solid model. The completed parts are output to be 3D printed, which requires significant post-processing work from the students in sanding and assembling their designs, particularly in priming and spray painting the finish, and understanding the additional tolerances that the paint finish requires. As they complete the physical assembly of the models, they also produce high quality digital renderings, and animations to show exploded views and other features of the design. Thus the students gain experience of a multifaceted approach to digital design that is inherently grounded in the physical model.

6 LEVEL 6: DEVELOPING PERSONAL PRACTICE

At Level 6, students are expected to demonstrate their design skills by applying them at a higher cognitive level through self-directed ‘major projects’. The teaching at this stage is predominantly through one-to-one tutorials. The students propose a design brief (through negotiation with tutors) and spend the year exploring, designing, and developing a range of speculative answers to the posed research question. There is a requirement for a highly resolved, functional prototype to be presented at the final submission, but also the expectation that this is the latest in a long string of experimental models throughout the year, using both physical and digital methods as appropriate to the project and the design stage. This is a well-established model in undergraduate design pedagogy; the relevance to this paper is in the observation of a tendency amongst students to procrastinate with physical model making, and a reluctance to move from either paper or screen-based representations into the physical realm. Speculated reasons for this included misplaced faith amongst students in the authority of CAD based representations, and the perception that greater marks might be awarded to explicit and precise digital models, regardless of the quality of the underlying concept, following Sennett [3]. In response to these concerns, a subcomponent assessment point was introduced to the project, with a submission in February of ‘proof-of-principle’ and ‘sketch’ models. This simple expedient of making explicit the requirement for early stage physical prototyping has paid dividends in pushing students to take the leap into making, producing a range of form exploration models in foam or similar, ergonomic rigs to explore human-scale interfaces, technology layout schematics evidencing potential product architectures, and prototype electronic circuits using open-source electronics prototyping platforms such as Arduino. This has provoked a renaissance in the art of multi-modal tinkering; both digital CAD and coding excursions and physical experimentation with components and form have become part of the same iterative design loop, using these experiments to feed their design development.

7 ASSESSING THE UPTAKE OF THIS APPROACH

In order to explore the effects of the pedagogical approach illustrated in the previous section, a survey was conducted of current Level 6 (final year) students from the cohort that will graduate in the summer of 2015. This was the first year group to have been subject to the new teaching model introduced in 2011. The questionnaire design was based loosely on that of Robertson and Radcliffe [4], but was adapted to fit the student cohort and their level of experience. 14 students responded, which is approximately 1/3 of the cohort. The first question simply asked how often students chose to use CAD as in their normal design practice. It was emphasized that this referred to CAD use by choice, as opposed to when required to as an explicit part of coursework marking criteria. None of the respondents replied that they “never” use CAD. 36% stated that they use CAD “occasionally”, 36% “about half of the working time”, 21% “most of the working time”, and only 7% “constantly”. Thus, 64% of the respondents indicated that they use CAD at least half of their working time. The next few questions explored the frequency of use of five different modes of working, using both analog and digital techniques, in four design situations, as described in Table 1.

Table 1. Modes of working and design situations explored in the study

Modes of working:	Design situations:
• Working directly with a CAD program • Using output from a CAD program such as printouts or 3D printed models • Using physical models produced by analog (manual) methods • Verbal discussions • Free hand sketching	• Communication of an immature design concept • Communication of a mature design concept • Visualisation of an immature design concept • Visualisation of a mature design concept

Students were requested to rank their use of each method of working, in each of the four situations, by frequency of ‘very often’, ‘often’, ‘occasionally’, ‘rarely’ or ‘never’. For the purposes of a comparative analysis, responses of ‘never’ scored 0, ‘rarely’ scored 1, etc. up to 4 for ‘very often’.

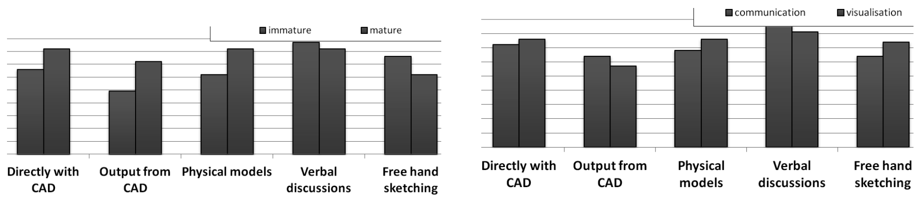

Figure 1. Comparison between preferred mode of work when designs are immature or mature, and comparative use of different modes of work

For the comparison between immature and mature design stages, the results for both communication and visualization modes were combined. At immature stages, students favoured the use of verbal discussions and freehand sketching over the use of CAD, but still used CAD more than physical modelling, either as digital output resulting from CAD use, or constructed by manual means. At mature design stages, free hand sketching was, predictably, the least prevalent. Physical models, verbal discussions, and working directly in CAD were used in equal amounts.

For comparison between communication and visualization scenarios, the results for both immature and mature designs were combined. For communication, again verbal discussions took precedence by some margin, followed by the use of CAD; there was close parity across the other modes of working. For visualization of design ideas, there was again relatively little between all categories, except for ‘output from CAD’ which was somewhat lower.

The following two questions examined the effects of ‘bounded ideation’ resulting from the motivational state of the students when using CAD, and ‘circumscribed thinking’ as a result of the limitations imposed by the software.

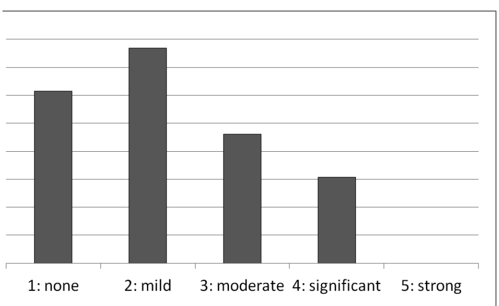

Figure 2. Extent of bounded ideation

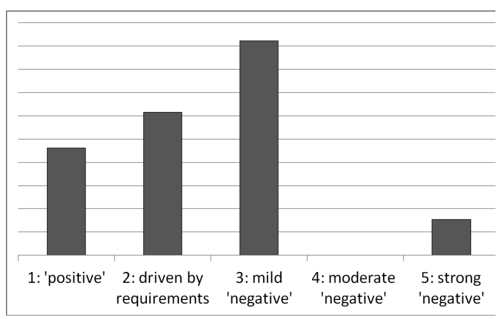

Figure 3. Extent of circumscribed thinking

The high frequency of responses 1 and 2 in Figure 2 suggest that bounded ideation is not significant issue for the majority (65%) of students. However, the remaining 35% of respondents (by comparison with 17% in the original study by Robertson and Radcliffe [4]) are still affected by moderate or worse motivational issues when using digital means of designing. This might be cause for concern in the context of CAD professionals, but on reflecting that respondents to this survey are at undergraduate level, it may be somewhat mitigated by the further training and experience students will undergo as their careers progress, or the option to choose career pathways within the industry that do not require high levels of CAD use.

With regards to circumscribed thinking, exactly half of the respondents felt that they their use of CAD was either driven solely by the requirements of the task, or that they were positively enabled by the digital tools to go above and beyond requirements. By contrast, Robertson and Radcliffe [4] found this figure to be 77% in CAD professionals. The remaining respondents in our study therefore all felt that to some degree their thinking was constrained either by the perceived limitations of the software or their own skills at using it.

8 CONCLUSIONS

This paper has described four examples of projects that illustrate our approach to blending physical and digital methods in design education. It should be emphasized that these are by no means comprehensive; brevity has dictated that much be left out. They are presented to provide some context to the educational experiences of the students who responded to the survey.

With only 14 respondents in total, the survey results should be treated with caution from a statistical point of view; this is a key limitation of this study. The results are presented to guide reflections on the pedagogical approach that may be of interest and value to other practitioners and educators in this field. Individual responses will, of course, have been influenced by the current educational stage of the students; despite being asked to reflect on their natural practice, irrespective of formal academic requirements, it is inevitable that their immediate context will have an effect.

Predictably, all of the students use CAD to some degree, but the fact that 64% of them use CAD more than half of their working time suggests that digital media are firmly established as a significant design tool of choice.

The comparison between modes of working at different design stages reveals some points of interest. Verbal discussions were overall the most prevalent. This might be a consequence of the style of teaching, which is to a great extent (and particularly at level 6) delivered through personal discursive tutorials; it also reinforces the social nature of professional design practice.

At immature design stages, students still prefer free hand sketching to the use of CAD, suggesting that they have not rejected traditional means of ideation, although CAD was slightly preferred to physical models. The parity between the use of physical models and CAD at mature design stages would support the assertion that students have engaged with the blended physical and digital pedagogical approach; this parity is also apparent in both communication and visualization of design concepts. Whether or not this is a causal relationship is less certain – it may simply be a reflection that our model is well aligned to current design practice and the natural inclinations of the upcoming generation of designers.

Physical models produced as an output from CAD scored generally lowest. This is possibly due to the nature of access to the technology: democratisation has not (yet) extended to the level that most students own 3D printers themselves, and thus their access to them is somewhat limited. As one respondent said in a comment "Digital ways of working [in CAD] can be done overnight, for free, in your bed room with a cup of tea. Model making requires access to a workshop and tools which costs".

The higher incidences of bounded ideation and circumscribed thinking (relative to those from CAD professionals [4]) reinforces the need for a curriculum that blends the best of both physically and digitally driven ways of designing and making.

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DETERMINATION OF CHARACTERISTICS AND ATTRIBUTES THAT ALLOW THE EFFICIENCY OF TECHNOLOGICAL TOOLS FOR THE CREATIVE STAGE OF DESIGN PROCESS

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ABSTRACT
The main objective of this research is to analyze the performance of design software to support the first stage of the product design process. To achieve this, a pilot study was developed to evaluate the efficiency of three design software commonly used in the creative phase of the design process, through an exercise of representation and conceptual exploration. Due to that this problem has been poorly studied, the study was exploratory, focusing on the ability to represent the first ideas in the selected software, leaving aside everything related to the mental activity of the designer. Based on the study, we can say that there are a number of features and attributes that allow certain technological tools to be efficient for representation and development of the first ideas in the creative stage of product design.

Keywords: Sketching, creative stage, design software.

1 INTRODUCTION
Nowadays there is a vast range of technological tools regarding processing software and devices that are created to make drawings quickly and easily [1]. But it should be noted that many of these technological developments may not be necessarily effective to support the creative stage of product design. This is due to the focus on the rapid three-dimensional representation, either through solids, surfaces or frames. This volumetric display is not the best way to represent the first ideas when it comes to designing a product. This is because the sketches, with its high degree of abstraction, allow the designer to reinterpret the shape and develop new ideas from previous sketches [2], [3]. We can say that there are software and devices that allow sketching, understood as a process [4] and others that allow the mere representation of ideas (centred in three-dimensional virtual drawing). That is, it is favoured in many occasions fast and easy three-dimensional representation of shapes, which limits the re-interpretation and mental re-processing.
The phenomenon of sketching has been studied from different perspectives and approaches [5], [6], [7], [8] but little evidence of research has been found on the role of design software in the first stage of the product design process [9]. Therefore, it is pertinent and relevant to conduct a pilot study to help us to identify and describe the properties of some software that allow quick representation of ideas, through figures and shapes with a high degree of ambiguity.

2 PILOT STUDY

2.1 Objective
To analyze the efficiency of processes and possibilities of representation of three of the most common design software, this through an exercise of representation and conceptual exploration. This study involved industrial three design students (novices) and three design professionals (experts), with reference to previous research [2], [10], [11].

2.2 Activity
The primary intention of the study was to lead three novice designers in performing freehand sketches of figures with high level of abstraction, plus to design proposals for a kettle. Secondly, novice

replicated the sketches made by hand, but now in the corresponding software. Finally, experts in a design software replicated the same sketches in the respective software, this with the intention of observing and comparing the processes of representation in computer interface. The sections of the pilot study are explained:

Section 1: The first part of the study consisted in performing sketches of basic volumes (sphere, cone, pyramid, cube and cylinder) with modifications of visualization (rotation in 3 dimensions) and transformation of the form (stretch, slice and compression). Auxiliary lines were used to better represent the volume.

Section 2: In the second stage of the study, the novice developed different design proposals of a kettle, which would consist only of four components: body, water outlet, lid and handle. The intent of this stage was to develop different proposals of a kettle, in side view, based on lateral transformations [3], considering the basic volumes of section 1 as the bodies. This limited the design possibilities, getting more homogeneous and equivalent formal solutions, which gave greater validity to the results of the pilot study.

Section 3: At the end of section 2 novice was requested to identify the proposals which in his/her opinion seemed the most innovative and/or attractive ones. This with the intention of taking them as a basis for the development of vertical transformations [3] in the section 3 of the study.

Section 4: At the final of section 3 novice chose the proposal that seemed the best, and then, drew it in 3 dimensions. The novice had the opportunity to sketch the object in perspective with support of auxiliary lines, shadows and texture effects.

Section 5: Novice replied all the sketches made by hand (sections 1-4), but now in the corresponding software: SketchBook Pro (Study A), SketchUp (Study B) and Illustrator (Study C).

Section 6: Experts replied all the sketches made by hand by the novice (sections 1-4) in the corresponding software. In addition to this, the expert of SketchBook Pro was requested to perform sections 1-4 of the study directly in the mentioned software, this previously to replicate the sketches made by the novice. That is, he was asked to perform the same sketches that novice in sections 1-4, but directly in mentioned software.

2.3 Variables

Independent variables: The independent variables include the software to compare (SketchBook Pro, SketchUp and Illustrator). The choice of computer programs for the development of this study was based on three aspects: popularity, accessibility and differentiation. The hardware selected was a laptop and input devices were chosen by the participants (a Wacom tablet for SketchBook Pro and mouse for SketchUp and Illustrator).

Dependent variable: A dependent variable was determined and called "efficiency", which considers runtime and quality. The runtime refers to the amount of seconds in the development of a sketch. Quality is defined as the fidelity of copying the personal sketches [12] on the selected software and on a scale of 1-2-3 (bad-regular-good respectively).

Extraneous variables: The extraneous variables correspond to the creative capacity, individual development of mental imagery [13] and skill in representing ideas through sketches of novice, as well as the degree of mastery in handling of software by novices and experts.

2.4 Subjects

The novices are three undergraduate Industrial Design students, which had an average domain of each software. In relation to the three experts, the choice was based on years of professional experience using the corresponding software (at least 3 years).

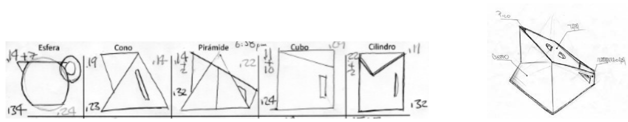
2.5 Contextual conditions

Novice and expert designers performed their exercises under equivalent conditions of work and in two schedules to choose: 10:00 am or 5:00 pm. The intent of this was to minimize the risk of fatigue and hunger. The sessions were conducted in offices of 2 x 3 meters , which had a desk and chair, and good natural lighting. The duration of the work sessions did not have a time limit.

3 RESULTS

Below are presented, as examples, sketches performed in sections 1-4 of the Study A:

Figures 1-2. Personal sketches performed in sections 1-2 of the Study A



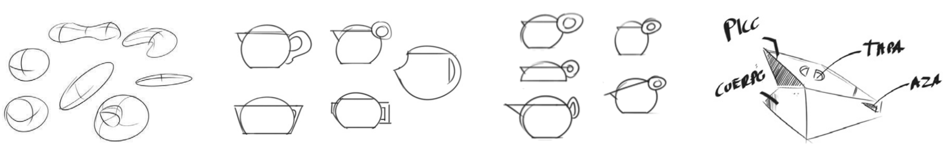
Figures 3-4. Personal sketches sketches performed in sections 3-4 of the Study A

In Figures 5-8 can see some of the sketches replicated by the novice in SketchBook Pro (section 5 of Study A).

Figures 5-6. Section 5 of Study A: Some sketches of sections 1-2, that were replicated in SketchBook Pro

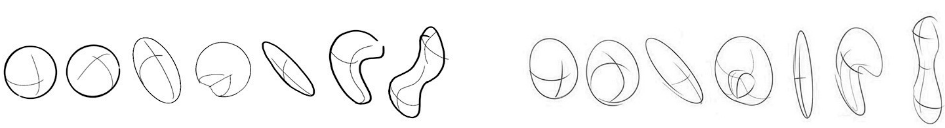
Figures 7-8 Section 5 of Study A: Some sketches of sections 3-4 replicated in SketchBook Pro

Some of the sketches replicated by the expert in SketchBook Pro can see in figures 9-12 (Study A).



Figures 9-12. Some sketches replicated by the expert in SketchBook Pro (sections 1-4 of Study A)

In figures 13-14, on the other hand, we can see sketches performed by the expert in SketchBook Pro:



Figures 13-14. Sketches performed directly in SketchBook Pro and sketches replicated, based on sketches previously performed by the novice

On the other hand, table 1 shows the runtimes and assessments of quality reproduction of sketches of the pilot study (Studies A, B and C):

Table 1. Averages, percentages y time-quality sketches performing factors of pilot study.

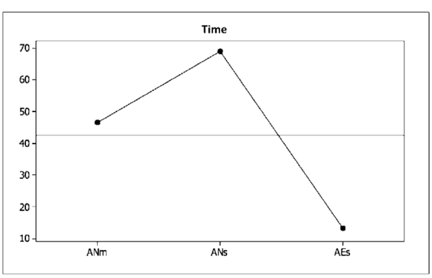
Averages-percentage-performing factors/Study	Study A SketchBook Pro	Study B SketchUp	Study C Illustrator
Time average (in seconds) in performing handmade sketches by the novice	142.1	145.4	164.4
Time average (in seconds) in sketches replicated in software by the novice	190	584.4	1068
Time percentage (in seconds) in sketches replicated in software by the expert	40.5	250.4	308.4
Time average in sketches replicated in software by the novice vs. expert	+ 369%	+ 133%	+ 246%
Time efficiency factor by novice	1.34	4.02	6.5
Time efficiency factor by expert	0.29	1.72	1.88
Quality average of replicated of sketches in software by the novice	2.78	2.37	2.93
Quality average of replicated of sketches in software by the expert	2.96	2.79	2.87
Quality average of replicated of sketches by the novice vs. expert	- 0.06%	- 0.15%	+ 0.02%

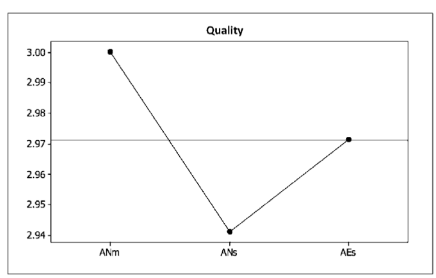
Table 2, meanwhile, shows the average of runtimes of sketching by the expert of SketchBook Pro directly in the software (Study 0) vs. the average of handmade sketches performed by the novices (Studies A-B-C):

Table 2. Average of runtimes of sketches performing by novice vs expert of SketchBook Pro

Studio A (handmade sketches)	Studio B (handmade sketches)	Studio C (handmade sketches)	Studio O (sketches performed in SketchBook Pro)
142.1	145.4	164.4	156

Finally, in figures 15-16 we can see two charts of time and quality averages of section A of Study A, where **ANm** means Study A-Novice-Handmade sketches, **ANs** means Studio A-Novice- sketches in software and **AEs** means Study A-Expert-in sketches in software):





Figures 15-16. Charts of time and quality averages (section A of Study A)

4 DISCUSSION AND FUTURE WORK

Based on the results of the study, three separate analyzes were conducted:

Analysis 1: The analysis 1 performs a comparative of time-quality among handmade sketches made by the novice vs. those sketches replicated in software by the novice vs. those sketches replicated in software by the expert. This for Studies A, B and C.

Analysis 2: Analysis 2 considered comparing time-quality among the three novices and experts (sketches replicated in software). The intention of this analysis is to find the software that allows faster and better quality performance (replicating sketches). The fact that there are no significant differences between the various figures and kettle proposals made by novice designers, allows us to make this comparison.

Analysis 3: Analysis 3 aimed to compare the time-quality of representation vs. replication of sketches by the expert in SketchBook Pro. As mentioned, this expert was asked to conduct the study sections 1-4 directly into the software mentioned, previously to replicate the sketches made by the novice.

Based on the results of these analyzes, it was observed that the SketchBook Pro software supports better the representation of the first ideas on the creative stage. This is possible precisely because, compared with Illustrator and SketchUp, SketchBook Pro enables the representation of figures with a high degree of ambiguity, through the free manipulation of a drawing instrument. If we look at the averages of runtime of the sketches performed by the expert directly in SketchBook Pro, in comparison with the handmade sketches performed by novices, we can see that the times are similar. This shows that the sketch on paper, or directly on SketchBook Pro, can be the same.

SketchUp, meanwhile, is emerging as an interesting way to represent objects and constructs 3D models. But it is precisely this possibility of three-dimensional representation only a way to represent ideas, but not to generate them. In fact, this software is more appropriate for the architecture, the above for its “constructive” character.

About Illustrator, we can say that is a software better than SketchUp, this respect to the representation of the first ideas on the creative stage. Illustrator is undoubtedly a design software that allows the representation of almost any shape, although runtimes are considerably larger than those used in SketchBook Pro.

Moreover, it is true that the three studied computer programs allow the representation of most geometries made by hand, but it is important to distinguish that SketchUp and Illustrator allow only the representation of ideas, but do not allow the “process of sketching" . This is due to, just to mention three characteristics, the speed of execution, high degree of ambiguity capacity and the free trace. In its favour, we can say that these programs can apply colours, textures and other effects, important issues for the communication of design proposals, but not important in the first stage of product design.

It is also important to mention that the possibility of copy / paste, in Illustrator and SketchUp, allows vertical transformations can be performed in a faster way. This was observed at the time of execution of the sketches in the software (Section 3), this in novices and experts.

As for the design of the study, we can say that although it is perfectible, it is considered that the design of the pilot studio is a good starting point for future research. In this sense, the general recommendations for further experiments consist of the following:

- Ensure equal working conditions for study subjects (eg: use the same space and the same time, in complete silence and without allowing music).
- Incorporate new software. The use of Paint and CorelDRAW, similar to SketchBook Pro and Illustrator respectively, certainly would allow more enriching results.
- Consider variations in terms of processing devices (such as tablets and smart phones).
- Measuring the efficiency of a software considering the use of different input devices (eg: mouse vs. Wacom tablet vs. touchpad).
- Investigate if a software interface promotes / inhibits the generation of design proposals, that with respect to sketching on paper.
- Based on the Analysis 3, we could ask the expert in software to perform their figures without line quality and without templates. This would reduce the execution times of the original sketches, which result in a greater validity of results.
- Incorporate, as far as possible, the missing components sketching: vision and mental processing (ability to reinterpretation and reprocessing of the already drawn).

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PRINTED ELECTRONICS, PRODUCT DESIGN AND THE EDUCATION OF FUTURE INDUSTRIAL DESIGNERS?

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ABSTRACT
The knowledge transfer of printed electronics technology to the designers of products has the potential to make a significant impact. There is a perceived lack of exposure to this emerging technology among industrial designers. It is desirable for student designers to be made aware of the opportunities such technology affords in order to enhance the design of future products. It offers a diverse range of new flexible form factors, no longer constrained by a rigid circuit board. In order to understand this disruptive emerging technology, a knowledge framework is required to support the education of student designers. This paper focuses on three essential areas of knowledge for a framework: approaches to technology readiness; techniques used for printed electronics, and a taxonomy of printed electronics. This combined information with design examples and a technology readiness grading would provide a basis for the development of understanding printed electronics. This paper concludes that a knowledge framework of printed electronics can be achieved. The translation of other fields into a taxonomy then utilised for educational innovations has previously proved successful within the context of Industrial Designers and Engineering Designers understanding the respective language of their disciplines. The overall goal of this research is to create a printed electronics taxonomy that can be used to educate student designers and enhance future product design outcomes.

Keywords: Printed electronics, product design, industrial designers.

1 INTRODUCTION

Printed electronics technology is a new but growing industry which is beginning to be integrated into product design. In the 2014 edition of the IDTechEx report, Das and Harrop [1]-predicted that "The printed, flexible and organic electronics market will be worth over $70 billion by 2024". A section of the report identified "an urgent need for creative product design" within the printed electronics field, highlighting the significance of knowledge transfer to designers.

The significance of printed electronics has been recognised by the International Electrotechnical Commission (IEC) who set international standards and conformity assessment for all electrical, electronic and related technologies [2]. The IEC technical committee for printed electronics, called 'TC 119', aim to implement the, "Standardization of terminology, materials, processes, equipments, products and health/safety/environment in the field of printed electronics" [2]. However, standards have still not been defined, nor put in place and appear to be work-in-progress, but demonstrates a level of advancement for this technology.

A European Union funded project titled Technology and Design Kit for Printed Electronics (TDK4PE) started in October 2011 and ran until August 2014. The aim of this project was to develop a methodology designed to, "abstract physics to a point where engineers could address physical design with sufficient certainty and great freedom for creativity" [3]. This interest displays a level of commitment to foster creativity within the printed electronics field and support the development of a common language for printed electronics. However, the methodology utilised focused on the way that the technology was designed and manufactured as opposed to strategies to transfer knowledge to designers.

This paper reports on research in which a knowledge framework is being created to increase and support understanding in the use of printed electronics technology by product/industrial designers, including student designers. It presents an opportunity to propose avenues of investigation into this technology with a focus on the specific needs of designers.

The translation of this technology into a resource has the potential to equip designers with accessible fundamental knowledge to facilitate informed decisions about how printed electronics can be used during new product development.

The approach taken focuses on three different areas: ‘approaches to technology readiness’; ‘printed techniques used for printed electronics’; and ‘a taxonomy of printed electronics’. This combined information will create a number of areas for the identified taxonomy of printed electronics, which currently stands as, interconnect, passive components, sensors, displays, power sources, and active components. These areas will be integrated with design examples and a technology readiness grading. This taxonomy will be used to generate tangible methods to increase understanding about the technology. This information, or the methods by which it is communicated, may also be altered for the benefit of student designers in successful understanding of this disruptive emerging technology.

Printed electronics technology has existed and been discussed for years, with some of the earliest printed electronics papers published in the early 1990s discussing the use of polymer bonding to create direct chip interconnect [4]. However, it is considered ‘new’ technology as it has recently started to emerge in a range of applications, and is at a point now where the ink formulations are reproducible and therefore commercial. This allows companies and also the public to purchase electronic inks and print with them, yet the results from this exposure has been limited in the types of applications from companies, and small home projects from the public. The extent of this technology within a product design context has not yet been explored, it seems that industrial design students have a perceived lack of exposure to this technology.

2 APPROACHES TO TECHNOLOGY READINESS

Identified by Engineering Research Centres [5], the Technology Readiness Level (TRL) system is used in industry to determine how close a product or piece of technology is to being commercially produced, from just a concept TRL 1 to ready for production and commercialisation TRL 9.

Mankins [6] identifies the first idea of articulating the status of a new technology was stated in 1969, with the plan for it to be used in a future space system. Combining the already established practice of the time ‘flight readiness review’ and the new concept of ‘technology readiness review’, which assessed the level of the new technologies maturity.

The National Aeronautics and Space Administration (NASA) was the first to invent the TRL system, discussed by Banke, from NASA [7], the first scale was conceived in 1974 by one of NASA’s researchers, Stan Sadin, which consisted of seven levels; these were formally defined in 1989. NASA adopted a scale with nine levels in the 1990s, which then went on to gain widespread acceptance across the industry and is still used today. Makins [6] further defines this as being in 1995, when the scale was strengthened with the first definitions of each level, accompanied by examples.

TRLs were then embraced by U.S. Congress’ General Accountability Office (GAO) and also adopted by the U.S. US Department of Defence (DoD), along with many other organisations considering the TRL system too. The TRL system is considered proven in being highly effective in communicating the status of new technologies; NASA’s TRL system [8] is still currently used.

The Centre for Compact and Efficient Fluid Power (CCEFP) TRL system [9] which has been adapted from NASA’s TRL system, differing in the language in the scale in order to create broader meaning and applicable to their terminology and technology. One example of this is in TRL 3, in NASA’s system it was “Analytical and experimental critical function and/or characteristic proof-of-concept” [8], and in CCEFP’s version, it is “Proof of concept research (bench scale)” [5]. CCEFP are a national science foundation engineering research centre, demonstrating how others have adapted the system to fit their own field.

An issue often noticed typically between TRL 4 and TRL 6 is the ‘Valley of Death’ which is between pre-competitive research and where industry is interested for commercialisation. To bridge this ‘Valley of Death’, designers can offer the technology an application; which often inspires industry to invest if it will boost their profile or generate revenue for their company/business, so educating designers about the technology could potentially be necessary for getting it from just a prototype to a fully working product or application which is commercially available.

As discussed by Markham [10], Bruce Merrifield first used the phrase ‘Valley of Death’ in 1995 when referring to the challenges of transferring agricultural technologies to Third-World countries.

A good visual example of this 'Valley of Death' is further defined by the Centre for Process Innovation (CPI), who help clients to assess the feasibility of their ideas and provide advice on how to move forward, however they define this 'Valley of Death' as between TRL 4 and TRL 7, referred to as 'The Innovation Chain' bridging the gap between academia and industry. In their business model, further definitions of exactly what they offer for universities and businesses combining a "technology push with business pull to drive forward those ideas" [11].
The Technology Strategy Board's (TSBs) [12] TRL system is a good comparison to the others as TSB are non-biased. They also look at the TRL system against funding sources, further highlighting the divide between university research and companies/industry; but looks at it positively as 'the innovation gap' rather than the 'valley of death'.
A composite table was created to easily compare existing up-to-date TRL scales from the National Aeronautics and Space Administration (NASA) [8], the Centre for Compact and Efficient Fluid Power (CCEFP) [5], the Centre for Process Innovation (CPI) [11], and the Technology Strategy Board (TSB) [12], selecting the most relevant parts to be used for a TRL scale to be adopted for this printed electronics research. The wording is critical when selecting the most appropriate for this topic as it needs to be in the right context, for example, NASA's TRL 9 definition would not be appropriate as it refers to this level as being "flight proven" [8]. In this case, this wording is only appropriate to be used within this aerospace TRL scale, as it is too specific to that field. Also in cases where the definition is the same, such as when looking at TRL 1 for both CPI and TSB, both defined as 'Basic idea', the information is used from the source that is least biased to their industry/topic, and also which is most respected/recognised to validate the decision, so in this particular case, TSB was used.

2.1 TRL approach adopted for this Printed Electronics Research

Using a combination of the TRL systems, considering the information and layout, a series of images were created to help relate this TRL system directly to printed electronics, which can be seen in the TRL system below (***Figure 1***). It has been created as it gives the research a greater depth of analysis, it also helps for contextualisation and to determine which TRL is related to which stage of printed electronics, and how close the technology/product is to commercialisation. Using this TRL system created for printed electronics, examples can be analysed to determine the findings and also assign the TRLs achieved in each example.

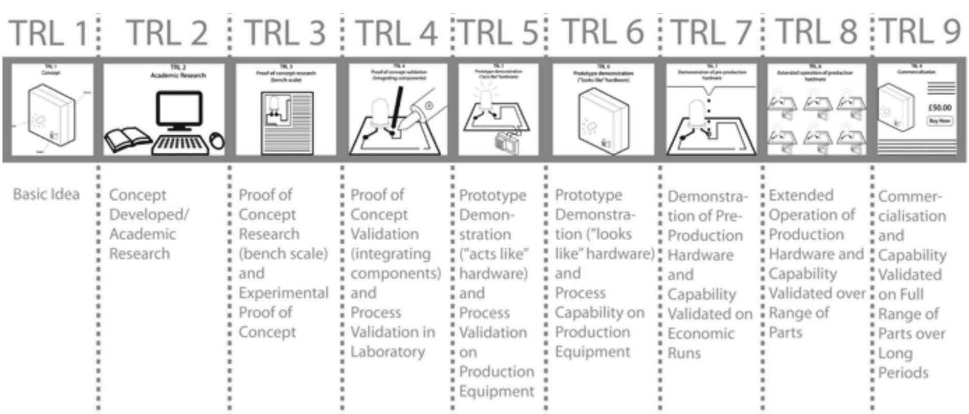

Figure 1. TRL system for Printed Electronics

medicine, mechanics and repair, social networking, entertainment, military, and navigation have made use of AR. Recently, research and development examples of AR have also gained public attention, with the AR head-mounted display Google Glass (developed by Google X) being one of the most widely known.
Until recently, AR was the preserve of large budgets and significant infrastructure. In the intervening time, AR has become accessible and affordable, such that AR applications can now run on smart phones, and are able to display digital content such as 3D models and animations onto 'augmentable' surfaces. There has been research on the uses of AR in industrial design activities, including: visualization of products, usage simulations and ergonomic analysis [5]; virtual design environments,

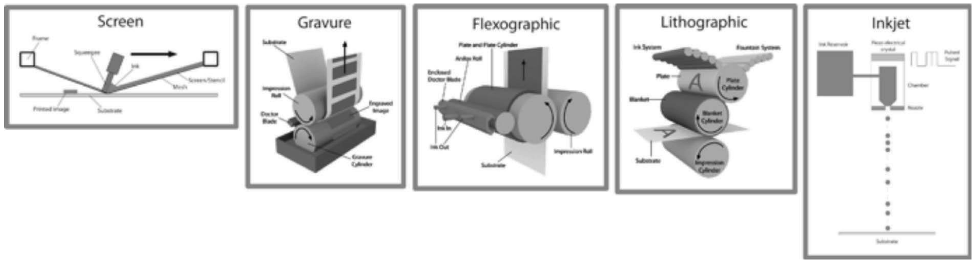

Figure 2. Printed techniques used for printed electronics

The process resolution and throughput are more considerations to be taken into account when making decisions, (***Figure 3***) as it is essential knowledge for choosing which process is best for the job. As discussed by the Organic Electronics Association (OE-A) [13], the resolution for each of these processes used for printed electronics can differ greatly. The type of product and usual design manufacture choices or scale, such as if it is a one-off, mass or batch production, will also help in decision making when designers consider these options.

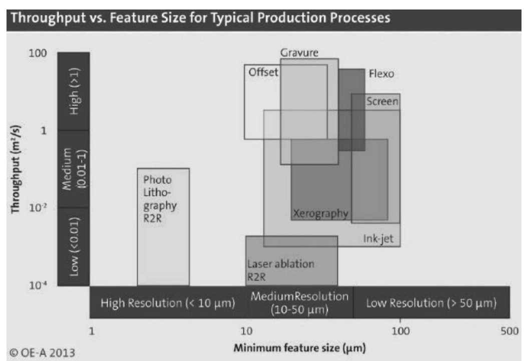

Figure 3. Resolution and throughput for a variety of processes

4 A TAXONOMY OF PRINTED ELECTRONICS

The translation of other fields into taxonomies for educational innovations for designers has previously been proved successful; such as in coding analysis when exploring complex patterns in the activity of design practitioners [14]. In Oxman's work, taxonomies were used to expand the inter-relationships between design and technology with the developments of fabrication technologies and digital design to be used to "educate designers to function as material practitioners" [15]. Others have translated information into taxonomies to be used as an educational innovation for designers, such as in Ahmed's work [16] on developing an intuitive design knowledge index for engineering designers. Pei's work on the development of a "teaching and learning tool in design education" [17] that builds a mutual language for inter-disciplinary collaboration during 'New Product Development (NPD)' between industrial designers and engineering designers achieved this by creating a taxonomy generated that comprised of "35 forms of sketches, drawings, models and prototypes" [17] when looking to bridge differences in design representations. Pei then built on this research [18] by creating a taxonomy of this information to be used by industrial designers and engineering designers in this NPD stage and then incorporated visual design representations (VDRs) creating a refined taxonomy, each image supported the definition of each taxon.

It seems possible at this point in the research to formulate a taxonomy of printed electronics. This arrives at six key areas based on the global capabilities. These six categories are Interconnect, Passive Components, Sensors, Displays, Power Sources, and Active Components; they are presented in the chronological order of their initial development. The taxonomy helps to determine the gaps in the capabilities. The order of the six areas are displayed in the chronology of evolution, for example, in order to achieve Passive Components, Interconnect must be achieved first. Active Components are holding up the evolution of printed electronics as they are the most difficult to produce, and only a few have been achieved.

These six areas have been chosen to help the designers learn, for example, sensors are a passive component, but when designing they could be viewed as a stand-alone element to consider or incorporate into a design as it serves a defined tangible function, such as detecting temperature or gas. There are overlaps in the taxonomy, but it is aimed to transfer this topic knowledge across in a way that designers can understand and relate to.

The structure of the taxonomy begins with the six different areas, for example starting with the section 'Interconnect', followed by the subsection 'Conductive Inks', then the manufacturing processes (e.g. Screen, Gravure, Flexographic, Lithographic and Inkjet) in chronological order of when each was first used in printed electronics (using the earliest published example). Within these manufacturing processes, a range of up-to-date examples has been used in this research as evidence to determine which technology readiness level (TRL) each process has reached (***Figure 4***). Interconnect is quite a simple example to provide as it only has one subsection, and it can be manufactured through all of the printing methods and each are at technology readiness level (TRL) 9. In other sections and subsections the TRL numbers differ, and some subsections are not produced by all of the printing techniques. This information enables the researcher to determine which information is necessary to include or exclude from the information presented to the student industrial designers. This process and TRL assessment along with examples of application provides a structure for this technology when teaching.

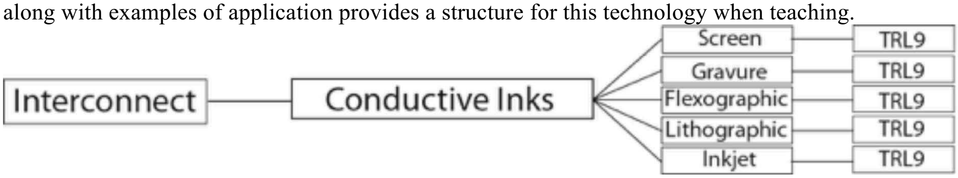

Figure 4. Taxonomy for Interconnect section

5 DISCUSSION

The work of Varekamp [19] discusses the relationship between industrial designers, and electronics. Varekamp states how industrial designers have a limited technical knowledge when it comes to the electronic domain, however they compensate by having discussions early in the design process with external electronics experts. Varekamp mentions the possibility of discussing "electronics in a "designerly" way" [19] but there are downsides to this current method of communication from designers to electronics experts as the designers use little technical terminology and it also limits the exploration of electronics, and the designer to fully design product behaviour. A need for a practical, information source to be used in design projects, by industrial designers was emphasized by Varekamp, and how industrial designers' education still lacks the topic of the "feasibility of electronic technologies" [19]. Varekamp concludes with the goal to "empower industrial designers to change from integrating electronics to: designing integrated electronics, its product behaviour and influence on user experience" [19] by using a framework that combines "design methods and tools that facilitate communication with experts that goes further than feasibility" [19].

In devising a taxonomy of printed electronics it unveils any uncertainties within the technological capabilities. Seeing the technology mapped out in this way will hopefully help people to identify what is and is not currently possible in printed electronics. Whilst the information is displayed for ease of understanding and clarification of printed electronics capabilities, it is to be used for analysis to aid teaching, in deciding which information is appropriate to present to student industrial designers, not to be the information presented directly to them. Information presented to students would be in a different form, such as existing product examples and process diagrams to aid learning. However, when the designers have understood the technology, this taxonomy could be an advanced point of reference for them at a later stage, showing them more clearly the feasibility of printed electronics. Similar to the work of Varekamp, this taxonomy would be a feasibility framework, but communication between industrial designers and printed electronics experts would still be necessary, until a mutual language is achieved.

6 CONCLUSIONS

The taxonomy of printed electronics, constructed through this research, provides insights into the state of the art of this disruptive technology. These insights can inform the construction of a framework to transfer knowledge to educators of student designers. With printed electronics ready for manufacture, this could also help alter perceptions of the technology and open up opportunities for industrial designers and the technology through the design of innovative products.

The technology has a sustainable approach to materials, and creates both form and function; this will influence future design greatly, if designers are educated about this technology. The growing range of substrates that can be printed on and used in design, such as glass and fabrics, opens further avenues for designers to explore diverse design, in quality products.

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The 17th International Conference on Engineering and product Design Education was hosted by the Loughborough University Design School in partnership with the Design Education Special Interest Group (DESIG) of the Design Society and the Institute of Engineering Designers (IED). The conference brought together representatives from Education, Design Practice, Industry and Government agencies that have an interest in developing new approaches and direction in Design Education.

"Great Expectations: Design Teaching, Research & Enterprise" was the conference theme and discussed the challenge for Higher Education Academics to meet the expectations placed upon them, to succeed in design teaching, design research while also fostering relationships with Industry toward collaborative design practice.

The aim of the conference was addressed through the following topics:

- *Informing Design & Engineering Pedagogy with Research & Enterprise*
- *Technology Integration, Application and Knowledge Transfer*
- *Bachelors, Masters and PhDs in Design & Engineering*
- *Design & Engineering Metrics & Assessment*
- *Promoting Creativity and Innovation in Design & Engineering*
- *Industrial Steering of Design & Engineering Education*
- *Design & Engineering Pedagogical Practice*
- *Project/Problem Based Learning*
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The 17th International Conference on Engineering and product Design Education was hosted by the Loughborough University Design School in partnership with the Design Education Special Interest Group (DESIG) of the Design Society and the Institute of Engineering Designers (IED). The conference brought together representatives from Education, Design Practice, Industry and Government agencies that have an interest in developing new approaches and direction in Design Education.

"Great Expectations: Design Teaching, Research & Enterprise" was the conference theme and discussed the challenge for Higher Education Academics to meet the expectations placed upon them, to succeed in design teaching, design research while also fostering relationships with Industry toward collaborative design practice.

The aim of the conference was addressed through the following topics:

- *Informing Design & Engineering Pedagogy with Research & Enterprise*
- *Technology Integration, Application and Knowledge Transfer*
- *Bachelors, Masters and PhDs in Design & Engineering*
- *Design & Engineering Metrics & Assessment*
- *Promoting Creativity and Innovation in Design & Engineering*
- *Industrial Steering of Design & Engineering Education*
- *Design & Engineering Pedagogical Practice*
- *Project/Problem Based Learning*
- *Benefits of Collaboration in Design & Engineering*
- *Infrastructure & Learning Environments*
- *User Experience in Design*
- *Globalisation & Mobility of Graduates*
- *International Collaboration*
- *Ethics & Social Issues*

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Great Expectations: Design Teaching, Research & Enterprise

3rd - 4th September 2015

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