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I am very grateful to Erik Bohemia for approaching me in August 2017 with the suggestion of guest editing a section of this issue. Erik and I form part of the organising committee for the International Conference on Engineering & Product Design Education (E&PDE) and I have selected six papers from the 19th E&PDE Conference, held in September 2017 at the Oslo and Akershus University College of Applied Science. 160 delegates from over 25 countries presented 117 papers, including 16 from students, on the theme of *Building Community: Design Education for a Sustainable Future* and the papers that I have chosen to represent a broad cross-section of those, covering a range of topics of interest to those engaged in design education, and they all provoked much debate and discussion. The papers presented here have been expanded and updated to take into account feedback received from other delegates at the E&PDE conference.

The E&PDE annual conference series started in 2000 and is organised jointly by the Design Education Special Interest Group (DESIG) of the Design Society and the Institution of Engineering Designers. E&PDE 2018 will be held in the new Dyson School of Design Engineering at Imperial College, London, and is being jointly organised with the Royal College of Art, London with the theme of *Design Education: Diversity or Conformity?* The conference series stays in the UK next year with E&PDE 2019 *Towards a New Innovation Landscape* being hosted by the Department of Design, Manufacture and Engineering Management, University of Strathclyde, Glasgow.

The theme of building communities and sustainable futures inspired many of the authors, and the first three papers that I have chosen reflect this desire for new design thinking and new ways of working to build better solutions for all users. It is clear that many of the authors were inspired by the theme of *Design Education: Collaboration and Cross-disciplinarity* from the E&PDE 2016 Conference in Aalborg University, Denmark, with many examples of papers from mixed discipline teams or from academics working alongside colleagues from industry or NGOs. The final three papers that I have chosen discuss how colleagues have worked with others from different teams within their universities or from external organisations to bring valuable new insights into their education environments.

Anne Britt Torkildsby (The Norwegian Research Laboratory for Universal Design, NTUT Norwegian University of Science and Technology) discusses her development of a critical design method in *Critical Design in Universal Design Settings – Pedagogy Turned Upside Down*. This method has been conceived as a way for students to explore immersion in extreme environments such as hospitals and prisons, and to consider the wellbeing of users in these situations. By adapting this method to universal design problems, she hopes to develop future designers that approach designing for all users in new and novel ways. Turning traditional universal design processes upside down, her method asks what it means to design for fundamental human needs. Her design method is a 3-step approach developed through 8 workshops in Scandinavian Design Schools with students from a range of design backgrounds. Students found this new way of design thinking liberating, and it changed their view of problem solving by turning traditional pedagogy upside down. The method contributes to universal design as a teaching and learning method, and it helps students to think, analyse and evaluate in a critical manner.

In *Developing Empathy for Older Users in Undergraduate Design Students* Andree Woodcock (Coventry University), Deanna McDonagh (University of Illinois) and Jane Osmond (Coventry University) argue that empathy is a key skill for designers and describe their efforts to ensure that her student appreciate and understand users with different abilities, and how they engage with transport. By striving to incorporate and provide opportunities for empathic design projects in the curriculum she uses low fidelity, experimental prototypes to expand students' empathic horizon. They give ways of understanding 'the other' through 'quick and dirty' techniques scaffolded with a reflective cycle to extract knowledge and learning from the experiences. Her 'framework of ideation' has been implemented through a cohort of final year design students where they are given impairments to their vision, hearing, mobility and touch. The students experience full immersion through experience prototyping which left students feeling vulnerable and heightened self-conciousness, thus increasing their ability to empathise with others, and hopefully go on to design products that are more suitable for their needs.

Linda Shore, Louise Kiernan, Adam DeEyto and Deirbhile Bhaird (University of Limerick), Anne Connolly (Ireland Smart Ageing Exchange), P J White (Institute of Technology Carlow), *Older Adult Insights for Age Friendly Environments, Products and Service Systems,* Tracy Fahey (Limerick School of Art & Design), Siobhan Moane (Limerick Institute of Technology) form a collaborative coalition of academic institutions in Ireland that have organised co-design symposia to show how design can affect change and influence policy. This paper highlights the importance of needs requirements for age friendly environments and involving students in participatory design research, and they use Ezio Manzini's definition of co-design as a "social conversation" from his 2015 book Design, When Everybody Designs – An Introduction to Design for Social Innovation (MIT Press). The authors stress the role of co-design and co-creation, both expert and nonexpert, in the ongoing wave of social innovation toward sustainability and inclusive design.

Gary Underwood (Bournemouth University,) and John Powell (Royal National Lifeboat Institute (RNLI)) describe their experiences of resolving design problems in low-resource communities as sustainably and ethically as possible through responsible use of local resources in *Rescued by Design: Enabling Low Resource Communities to Reduce Global Drowning*. They concentrate on the RNLI initiative to reduce global drowning statistics, and use this project in Bangladesh, where 50 children drown every day, as a vehicle to understand if students can gain sufficient understanding of relevant issues to design for unfamiliar cultures. They also ask why communities are looking for designers from the other side of the world to provide low tech solutions for local problems. By highlighting the problems and benefits of low resource design projects, they discuss problems of validation, compliance, moral and social issues. Through a series of co-design and co-creation projects they are producing a community of practice – *Rescued by Design* – a resource hub related to lifesaving equipment. They end with a call to a global society of local innovators and designers based on innate local traditions of cooperation and community action to co-create solutions to design problems in low resource societies.

Decision Making in Product Design – Bridging the Gap Between Inception and Reality Julian Lindley (University of Hertfordshire), Richard Adams (University of Hertfordshire) and Les Wynn (HCL Technologies) discusses the development of a structured and validated approach to decision making within the design process. A pilot study was conducted whereby a commercial decision-making tool from HCL Technologies was introduced to final year students to validate the selection of appropriate designs from a range of concepts against a hierarchy of criteria. Design decisions increasingly need to be justified and validated, and the authors discuss a grey area of uncertainty, a design decision gap within current design processes such as the Design Council's Double Diamond model. Tools and techniques such as an HCL's Idea Filtering Analysis, discussed in the paper, could prove useful in helping students to understand what constitutes a rigorous design process, and help to highlight areas where further time needs to be spent to develop their understanding.

In *Mobile Eye Tracking in Engineering Design Education* Stephan Hess, Quentin Lohmeyer, Mirko Meboldt (ETH Zurich) consider how students perform functional analysis of complex machines and systems. By asking what prior knowledge students need and how they can be helped to understand the functions of the system, the team from ETH Zurich have developed a mobile eye tracking system. This has been used to compare high and low performing behaviour for undergraduate mechanical engineering students, obtaining insights into user's cognitive processes. They found that a basic engineering design education was a prerequisite, as this imparts a suitable mindset from which to improve their ability in functional analysis. The work also confirmed that a wide technical knowledge base is required in order to understand complex systems, including the relevance and function of each part or subsystem in the whole. It also had a great bearing on the time taken to understand some of the more complex or unusual parts, making this work particularly relevant in time sensitive applications or in technical examinations.

Finally I would like to thank Prof Kay Stables for her help and support in the preparation of these papers as well as all of the authors for working with me in such a timely manner to get these papers prepared for publication. I hope that you enjoy reading the papers and draw some inspiration from reading them.

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23.2

Critical Design in Universal Design Settings: Pedagogy turned upside down

Anne Britt Torkildsby, NTNU Norwegian University of Science and Technology; The Norwegian Research Laboratory for Universal Design, Norway

Abstract

Universal design thinkers are needed now more than ever. The world is facing one humanitarian crisis after the other, forcing people to flee their homes and resettle elsewhere without knowing anything about the local language, traditions, and way of life. Moreover, an ageing population is in need of (housing) design that facilitates long-term accessibility and hence homeowners 'ageing in place' safely without losing their independence. Moreover, nations such as Japan, Spain, and Norway have made diversity and inclusion part of their national political agendas to ensure that future products, buildings, and exterior spaces, are inherently accessible to all. Taking all of this together, it is imperative that the next generation of designers is informed about and skilled at dealing with future challenges and demands, however complex they might be.

Originally developed as a powerful tool for designers, architects, and others to explore 'extreme environments', such as hospitals and prisons, and the ways in which objects impinge on existential wellbeing, the critical design method is now gradually being adapted and applied to the field of universal design. Two series of workshops have been conducted to test and further develop this way of thinking about design for educational contexts. The purpose of this paper is to describe the process of applying the critical design method to various universal design contexts, and to discuss the results thus far. Furthermore, the paper examines to what extent critical design is an appropriate method for questioning and improving the field of universal design.

Key words

critical design, universal design, design methods, educational practises, workshops, wellbeing

Introduction

1.1 Universal Design

According to Mace, who is credited with coining the term in the mid-eighties, 'universal design' (UD) is "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Centre for Universal Design, 2018). In the last ten years, however, UD as a design code or philosophy has been broadened in terms of its scope to include the wider issues of subjective values such as social inclusion and self-actualisation (Zöller & Wartzack, 2017, p. 55-69). Thus, a more recent and accurate definition is as follows: “A process that enables and empowers a diverse population by improving human performance, health and wellness, and social participation” (Steinfeld & Maisel, 2012, p. xi). Zöller and Wartzack think along similar lines, recently proposing that UD should prioritise the objective and subjective well-being of users (2017, p. 55-69). Moreover, because there is currently no end to the needs, wants, and desires of the public as relating to improved human performance, health and wellness, and so on (Steinfeld & Maisel, 2012, p. 90) – nor will there ever be – future UD thinkers[1] should always keep their knowledge of UD current, this paper argues. Among other things, this means that academia will have to deliver consistently outstanding teaching and learning outcomes. This will be undertaken in order to equip the universal design thinkers of tomorrow – be they designers, architects, engineers, or other professionals – with novel ways of approaching the UD process.

Further; what if design educators were to turn the key terms and concepts relating to UD upside down (metaphorically speaking)? This could be undertaken by implementing, early in the design process, a CDM that makes it possible for students to focus on “what it means to design for a fundamental form of being human”, rather than “what the thing we design is intended to do as we use it” (Torkildsby, 2014, p. 30). Would students have different learning outcomes, or even a deeper understanding of what it means to be human in the physical environment? Furthermore, can critical design thinking and a certain amount of provocation provide them with alternative starting points for creative thinking, and thus add more tools to their problem-solving toolboxes (Torkildsby, 2017)[2]?

1.2 Existential designial analysis; the critical design method

Existential designial analysis (EDA) is, in short, a critical design method (CDM) that has been developed as an alternative way of thinking about design in ‘extreme environments’: those that people are unable to leave – for either physical or mental reasons, and temporarily or permanently – and which do not support what is considered to be a ‘normal’ state of existence (Ibid., p. 22), such as intensive care units (ICU) and remand prisons. While traditional design methods such as those of Archer (1965) and Jones (1970) merely address the function(s) of a product, service, system, and/or process, the CDM focuses on the impact that the product has on the user while they are using it. In other words, instead of asking “what does a prison uniform do?”, for example, the emphasis is on “what is a prison uniform as a design?” (Torkildsby, 2014, p. 30). Moreover, employing it during the initial phases of a design process enables the designer to shift focus, from “analysis of the functionality of a design in use, e.g. by performing a functional analysis, to analysis of the form of

[1] Torkildsby (2017) considers UD to be a process rather than an end result, hence the term ‘universal design thinkers’.
[2] The main findings reported in this paper were originally presented at the E&PDE conference in 2017.

being human that a design in use defines" (Ibid., p. 7). In so doing, the designer is able to open up the design brief and examine it from perspectives that may otherwise be overlooked.

The CDM is rooted in 'critical design' – a term that builds on the attitudes of the Italian radical design school of the 1960s and 1970s, but was first coined by Dunne in 1999. Dunne and Raby argue that 'design can be described from two perspectives; 'affirmative design' and 'critical design'. Affirmative design "reinforces how things are now" as it conforms to cultural, social, technical, and economic expectations (Dunne & Raby, 2001, p. 58), and aptly describes the majority of design processes. Critical design, however, "rejects how things are now as being the only possibility, [and] provides a critique of the prevailing situation through designs that embody alternative social, cultural, technical or economic values" (Ibid.). Malpass describes critical design as an *affective*, rather than *explanatory,* practise because it "opens lines of inquiry as opposed to providing answers or solutions to questions or design problems" (2017, p. 41). The purpose of critical design is, in short, to make people think and so raise awareness, expose assumptions, provoke action, and spark debate (Dunne & Raby, 2018). Dunne, moreover, relates critical design directly to the critical theory developed by the Frankfurt school in the 1930s – which, in brief, aimed to not only understand the world but challenge that understanding (Gulliksson, 2015, p. 276) – and quotes Geuss's description of critical thinking: "Critical theories aim at emancipation and enlightenment, at making agents aware of hidden coercion, thereby freeing them from that coercion and putting them in a position to determine where their true interest lie" (Dunne, 2006, p. 150; Geuss, 1981, p. 55-56). Critical design has been used in recent decades to examine social, political, economic, and environmental issues in society: See, for example, the iconic *Faraday Chair* (1997) of Dunne and Raby, which provides shelter from the electromagnetic fields that are increasingly invading our homes (Dunne, 2005, p. 142-44), and Onkar Kular's *Hari and Parker* (2007), a speculative project that explores the increasing presence of domestic surveillance and information exchange (Kular, 2018). Similarly, Gavel et al.'s recent, Research Councils UK-funded project *Energy Babble* (2015) features an "automated talk-radio" plays various sounds and statements borrowed from various social media and online sources as a way of reflecting and commenting on the existing state of energy use in the UK (Gaver et al., 2015). These projects are just the beginning, according to the innovation and design-thinking researcher Mickahail, who claims that critical thinking and creative thinking must work together in order to ensure that innovation takes place in the design thinking[3] process (2018).

The CDM consists of a three-step design approach, which in turn is presented as a functional design manual – ready for use. The three steps are intended to guide a designer through the process of generating 'critical design examples' (CDEs) (Torkildsby, 2014, p. 20). According to Sanders, critical design uses 'probes' as "ambiguous stimuli that designers send to people who then respond to them, providing insights for the design process" (Sanders, 2006, p. 7). This correlates well with the intended function of CDEs, i.e. highlighting problems in extreme environments in order to identify

[3] 'Design thinking' was coined in the 1990s by David Kelley and Tim Brown of IDEO, and refers to a human-centred, structured process for innovation that can be applied to products, services, systems, etc. (IDEO, 2018).

the complications that may arise if this aspect of design thinking is ignored – hence, this is considered to be the 'dark' approach to design thinking. In other words, CDE are primarily intended to be used in problem-solving processes, such as the planning of a new hospital or prison, in order to foster innovation among everyone involved in the process. Thus, designers obtain improved knowledge of the relationship between humans and physical objects in extreme environments when creating CDEs, which function in the same way as critical artefacts, speculative design objects (Bowen, 2009; Dunne & Raby, 2013), and 'provotypes' (Mogensen, 1992; Boer & Donovan, 2012). This is to say that, by engaging with them, designers are challenged to leave their comfort zones and think outside of the box in order to find better solutions to design problems. Lenskjold has studied the use of critical artefacts, provotypes, and other forms of provocative design from an anthropological perspective, suggesting that critical artefacts, which function as transitional devices at different stages of a design process, are "objects of mediation between heterogeneous assemblages of stakeholders, contexts and concerns" (2011). This line of thinking perfectly matches the purpose and significance of CDEs within the framework proposed in this article. Bowen has suggested applying a similar method, termed 'critical artefact methodology', in participatory design and co-design processes. This research explores the effects of critical artefacts being used to provoke stakeholders to engage with artefacts, which in turn leads to reflection on the assumptions that underlie what is considered to be possible (2009, p. 190). In short, Bowen's conclusion is that even though critical artefact methods are not universally applicable, they are well-suited to "imaginative, open-minded stakeholders, 'in-tune' with the possibilities of novel situations" (Bowen, 2009, p. 217-18). This is particularly the case for designers, this paper argues, who may develop and adapt critical artefact methods within their own professional practice.

2 APPLYING THE CDM TO EXTREME ENVIRONMENTS

As is discussed above, the CDM was first developed with extreme environments, such as ICUs and remand prisons, in mind. In order to obtain extensive knowledge of these institutional environments to complement what has already been established through literature, interviews, etc., observations in the environments were conducted. The key issues were then identified, assessed (i.e. compared with 'reality' – the current research context), defined, and classified within a system (Torkildsby, 2014, p. 288-289). Furthermore, the theoretical framework was re-formulated in relation to EDA so as to be more practical, then formed into the three-step approach that in turn was compiled in a design manual. As a way of testing, exemplifying, and disseminating the CDM, eight workshops involving approximately 80 students were conducted in various design schools in Scandinavia in 2011 and 2012. Hundreds of CDEs were generated during the workshops, six of which are discussed in this article (see Chapter 3 of Torkildsby's *Existential design – Revisiting the "dark side" of design thinking* for more examples).

3 WORKSHOP SERIES #1 – BRINGING THEORY INTO PRACTICE

3.1 Structure

Although the length of the workshops varied between one and four days, the overall structure – the order of the activities and the amount of time spent on Steps 1-4 – remained the same, aside from Step 1 during those workshops which had a large number of students. Lunch breaks and so on were agreed upon following discussion with each class. Consent forms were signed and handed in before the end of the workshop – with participants able to withdraw their consent at any time – so that the data collected (pictures, sketches, quotations, etc.) would be available for use later in the project. It should be noted that the tutor shifted between the active role of a teacher, providing guidance when needed, and the passive position of an observer, 'drinking in' as much information as possible. The following example (Table 1) is from a one-day workshop:

Table 1. Workshop structure (Torkildsby, 2017).

Time	Activity	Step
09:00-09:30	Welcome and introduction by the tutor, followed by brief student introductions and an overview of the workshop	1
09:30-09:40	Introduction to functional analysis and the CDM, as well as a brief run-through of the differences and similarities between these two approaches to design	2
09:40-10:25	Presentation of four fictional settings, along with a demonstration of using the CDM by applying the three steps	3
10:25-11:00	Discussion and presentation of CDEs, including visual material from the field of critical design for inspiration	4
11:00-15:45	Presentation of the assignment, with the students being divided into groups (with a maximum of five in each), and the beginning of the group work	5
15:45-16:30	Presentation of the final concepts – the CDEs – followed by a discussion and summing-up of the workshop	6

3.2 Participants

All of the participants were students of some form of design; some were working towards a degree in textile design, while others possessed a strong background in industrial design. The participants came from both the BA and MA levels, and both genders were represented. Many nationalities were represented as most of the schools accept international students.

3.3 Procedure

The students were challenged to reflect on and discuss the reality of existing in an extreme environment prior to commencing work on the task. The scenarios that were touched upon included a person undergoing care in an ICU regaining consciousness after being sedated, and dreaming about being abducted and tortured by aliens or facing a firing squad, despite being in safe hands at the hospital. Similarly, in the context of prison, the students explored the idea of people being held on remand being deprived of (almost) all of their freedom as a means of punishment, despite the fact that a central tenet of justice systems is that the accused should be considered to be innocent until proven otherwise. The students created CDEs based on these ideas, examining everything from how being strapped to a bed in an ICU makes an individual feel exposed and fragile to the fact that those in remand prisons are vulnerable to violence, sexual abuse, and torture.

The students then used the three-step CDM to develop CDEs in response to given problems. Half of the students developed curtains, prison jumpsuits, bedding, or door handles for remand prison cells, while the other half created clothing, bedding, room dividers, or bedside lamps for ICU patient rooms. The creative process for tackling this assignment generally unfolded as follows: Discuss; reject the idea of designing something that is *affirmative* rather than *critical* and *explanatory* rather than *affective* (Dunne & Raby, 2001, p. 58; Malpass, 2017, p. 41); create a fictional setting (i.e. a fictional person and environment) as a basis for further development. Next, accept the existence of fundamental differences between traditional design thinking and the CDM; sketch; drink coffee or tea; discuss; decide on a concept to develop into one or more CDEs; eat lunch; sketch; possibly create one or more prototypes; discuss; present the outcome. Most of the groups produced more than one CDE, but all had to select one to present. The students were, for the most part, surprised by what they had achieved by the end of the day: “But this seems to be upside down?!”; “I’m not that into critical design – at least not until now, but I sure like this way of working with fiction to prove a point”; “Actually, I’m a bit ashamed that we came up with this…” (Torkildsby, 2014, p. 270).

The ‘dark’ way of thinking evoked both reflections and emotions in relation to the environments being discussed. One student whose grandmother happened to be in an ICU at that time, for example, understandably felt appalled at the prospect of developing CDEs that involved the idea of harming a bedridden person. That student, however, arrived the next day and was heard to say, among other things, “So we’re not supposed to be ‘nice’?!” and “Yesterday I felt sick. Today it’s just fun!” (Ibid., p. 246). The students came from a wide variety of schools and backgrounds, and felt that, regardless of the design method that they commonly used in their respective fields, this ‘dark’ way of thinking “doesn’t hurt anyone” (Ibid., p. 255); rather, it opens one’s eyes, even if one does not deal with critical design on a daily basis.

Figure 1. Students' work. From left to right: ICU bedding made out of metal sheets, to – quite literally – anchor the patient to their bed; a prison jumpsuit to cover the inmate's body, including the head, while leaving their buttocks exposed; a door handle for a remand prison cell that is designed so that the cell shrinks every time the prisoner tries to open the door (Torkildsby, 2017).

3.4 Trends and reflections

The most apparent trend discerned during the workshops was the significant differences between the students' approaches to the task. Those participants with a background in problem solving – in the sense that a process begins with the definition of a problem, and this is followed by a functional analysis or similar to define functions(s) – such as product and industrial design students tended towards being 'method- and concept-oriented', and generally created a concept and worked from there (Ibid., p. 257). Those participants with a 'material- and technique-oriented' approach to design – such as the textile and fashion design students – on the other hand, started the process by selecting a material and technique. They then created a method and concept that was a critical version of the already-existing object, rather than selecting materials based on a specific concept (Ibid., p. 196). It should be noted, however, that the resulting CDEs show that one of the two working methods did not produce 'more critical' design examples than the other; i.e. the CDM appears to work perfectly well for both design approaches.

The participants in the first two workshops found it difficult to begin work on the task of designing the CDEs, but solved this by starting the process with the creation of a fictional setting. The fictional people and environments provided the students with a narrative to work from and a framework for the CDEs (Ibid., p. 170; 189). From the third workshop onwards, however, the students were encouraged to develop settings in groups for their CDEs, and post-workshop discussions with the students revealed that this approach made the CDM less abstract and easier to grasp and subsequently apply.

Another observation made during WS1 (Workshop Series #1), was that the students approached one- and four-day workshops differently. During one-day workshops, the students generally rushed to settle on and carry out a single concept, but during the multi-day workshops the students took more time to explore different ideas and concepts before settling on one. Four one-day, one two-day, two three-day, and one four-day workshops were conducted as part of WS1, and it was concluded that three days provided sufficient time for the participants to grasp the concept, experiment, and develop several acceptable concepts in a suitable manner. This also prevented them from spending too much time on fictional settings, stylised renderings, building models, and supplementary films, as was the case during the longer workshops (Ibid., p. 244).

The students felt that eight hours was an acceptable length for the one-day workshop to function as an introduction, with one describing it as “a little like a vitamin injection” (Ibid., p. 215). A deeper learning experience and longer-lasting learning outcome, however, was felt to require more time in which to think about (and, moreover, *re*-think) and play with the material before settling on CDEs (Ibid., p. 168). This suggests that a longer design process resulted in more learning, but the time spent on creating the CDEs appeared to be less related to how critical the CDEs were – although whether this was due to talent or luck is difficult to say with any certainty at this point. It should be added that, although it was to be expected, the students with more experience of design methodology and designing (on any scale), such as many of the Master’s students who participated in the workshops, generally completed the workshop assignment relatively efficiently. In comparison, some of the second-year Bachelor’s students, for example, simply spent more time on the same tasks. This insight, in turn, informed decisions regarding future workshop participants.

3.5 Results

The students were free to choose the medium with which to present their result, and so the CDEs took the form of rough black and white sketches, colourful cut-and-paste illustrations, detailed scenario descriptions, simple mock-ups, elaborate models, short films, verbal presentations, and role-plays. Without doubt, however, the learning outcomes were much more important than any physical results produced, and the discussions at the end of each workshop revealed that most of the students felt that this way of thinking design was liberating in relation to their world of problem solving. Moreover, it seemed that the students (mostly) had fun developing CDEs: “This is kind of bad and fun at the same time” (Ibid., p. 216); “It’s fun to be a bit artsy…” (Ibid., p. 246).

With regard to the presentations at the end of each session, less finished or polished CDEs were generally the product of more (critical) questions having been asked and fruitful discussions held, leading, naturally, to a better understanding of the CDEs and more knowledge being generated about critical design in general. Similarly, the more loosely structured presentations felt more comfortable in the context of the class: gathering all of the participants around a table and talking informally about what each group had achieved – along with how and why – rather than ‘selling’ the result with intricate renderings and flashy models, appeared to be central to opening up discussions (Ibid., p. 199).

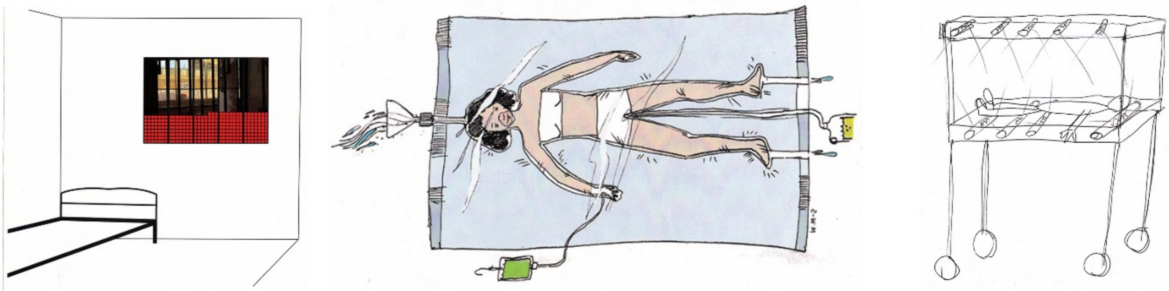

Figure 2. CDEs that were created during WS1. From left to right: Prison curtains that slowly block the view of the inmate; transparent bedding for use in an ICU ward to fully expose the patient; hospital bed dividers to put the patient 'in the spotlight', rather than acting as protection (Torkildsby, 2017).

4 APPLYING THE CRITICAL DESIGN APPROACH TO UNIVERSAL DESIGN

The physical environment, which includes housing, products, transportation systems, and buildings, is typically designed for the able-bodied; as Norwegian Design and Architecture states on its website, "Most products and services are generally designed for the average user – a typically healthy, right-handed, white, young male" (2018). Thus, those who have difficulty in walking or suffer from colour blindness, cognitive disabilities, and even incontinence fall outside this definition. Initially appearing during the civil rights movements of the 1950s, then subsequently applied in, among others, the field of architecture (Goldsmith, 1963) and in relation to commercial products and information technology (Mace, Hardie & Place, 1991), UD is a relatively new concept in design education. Viable methods of teaching have been established (Clarkson, Coleman, Hoskin & Waller, 2007; Vavik, 2011) but, as Denizou states, teaching UD requires a foundation of design methods that are based on, among other things, creation and simulation exercises (Denizou, 2016, p. 113). In addition, Zöller and Wartzack conclude that UD needs to consider not only physical ability in the search for well-being but the overall satisfaction of users – including motivations relating to and feelings towards a product or environment (Zöller, & Wartzack, 2017, p. 57). This is why the CDM should be a welcome contribution to the field; a means of exploring concepts in more detail and, most importantly, the fundamental relationships between people and objects (Heidegger, 1971; Borgman, 1984; Torkildsby, 2014).

5 WORKSHOP SERIES #2 – BRINGING THEORY INTO PRACTICE

5.1 Structure

The second workshop series consisted of three half-day workshops, all of which shared the same overall structure – i.e. the order of activities as well as the time spent on each part – and were identical to those of WS1 as regards administrative aspects.

Table 2. Workshop structure (Torkildsby, 2017).

Time	Activity	Step
12:30-12:45	Welcome and introduction by the tutor, followed by brief participant introductions and an overview of the workshop	1
12:45-13:15	Introduction to the CDM, including a brief explanation of how to apply it during the design process and a discussion and presentation of CDEs	2
13:15-15:45	Presentation of the assignment, with the participants being divided into groups (with a maximum of three in each), and the beginning of the group work	3
15:45-16:30	Presentation of the final concepts – the CDEs – followed by a discussion and summing-up of the workshop	4

5.2 Participants

The eight participants in the first workshop were researchers from a Scandinavian rehabilitation engineering and design research institute, while the twenty-five of the second and third workshops were occupational therapy Master's students from Norway. The participants were aged between 20 and 60-something, and both genders were represented.

5.3 Procedure

As in the previous workshops, the participants developed CDEs to solve a given problem, creating speculative design proposals for staircases, headphones, door entrances (i.e. frame and door), smartphones, and E-textiles. Because of the limited time as compared to WS1, there was less opportunity to discuss the physical environment prior to the beginning of the creative process, and the fictional settings were created in advance by the author to save time during the workshop. The fictional settings included descriptions of physical/psychological dilemmas, several examples of which are as follows: "Caroline (67 years old) has lost her peripheral vision and has poor depth perception, making crossing the road and going down stairs very difficult" (design task: staircase). "Elizabeth (48 years old) suffers from urinary incontinence, and as a result often avoids public transport due to the fear that the bus or train might not have an operational toilet – or any toilet at all" (design task: E-textiles). "Tom (37 years old) was diagnosed with multiple sclerosis 12 years ago, has poor balance, experiences difficulties in walking, and finds that he bumps into things every now and then" (design task: door entrance). A portrait of the fictional person accompanied the texts to further stimulate the imaginations of the participants.

The two groups had different ways of approaching the task, with the researchers performing a miniature version of a traditional problem-solving process, featuring ideation and concept development towards a result, while the Master's students quickly decided upon a solution. In addition, the students had a tendency to create CDEs that featured an element of cliché and pastiche, rather than letting the viewer, in the words of Dunne and Raby, "experience a dilemma, [and so decide for themselves;] is it serious or not? Real or not?" (Dunne & Raby, 2018). Despite their differences, the participants worked diligently throughout the workshop, and the topics that were discussed ranged from the extent to which our environments drive and direct our possibilities and actions to how the CDEs could be used to fuel a creative process – among not only designers, but also occupational therapists. Just as in WS1, the participants were positive regarding their experiences, aside from one who felt that this way of working was childish and a waste of time. To quote some of the participants: "This is like anti-universal design"; "What a great way to kickstart a project!"; "The critical design examples remind me of 'design probes' and 'provotypes'" (Gaver, Dunne & Pacenti, 1999; Mattelmäki, 2006; Mogensen, 1992; Boer & Donovan, 2012).

Figure 3. A visual impression of the workshops (Torkildsby, 2017).

5.4 Trends and reflections

That the researchers from the rehabilitation engineering and design institute worked differently to the Master's students from the occupational therapy programme was, as is discussed above, to be expected due to the differing backgrounds of the two groups. However, the extent to which the latter were less effective due to having little or no experience with design methods – and speculative design approaches, for that matter – and less honed creative/artistic skills in general is unclear. Similarly, whether this related to the limited time and consequent brief introduction to the theme, or a combination of these, is also uncertain.

This was the first time the fictional settings, i.e. the dilemmas of Caroline, Elizabeth, and so on given above, were presented to the participants prior to them commencing work on the task, and all three groups seemed to embrace the idea and benefit from it in terms of time. They quickly began to work, although in retrospect it is difficult to say whether this 'lost' time was actually what the participants needed in order to reflect more on the subjects in question and obtain a better understanding of the material (this realisation, moreover, provided insights regarding future workshops.) With regard to the element of time, and as WS1 showed, one-day workshops seemed to function as a ‘vitamin injection’, meaning that the half-day workshops barely offered a taste of the concept at its core. It is hoped, however, that a seed was planted in each of the participants, and that they at least know where to find more information about this way of thinking about design if they wish.

It should also be noted that all three groups conducted relevant discussions, both within each group and with the tutor; these revealed that, regardless of background, the participants were able to see the CDM as a way of “learning something new about something old”, in the words of one of the Master’s students. This supports the findings of WS1 – that the learning outcomes achieved as a result of hands-on experience seem to be much more important than the physical results produced.

5.5 Results

The CDEs were generally more ‘half-baked’ than those produced during WS1 and so less ‘critical’, which was to be expected due to the differing backgrounds of the participants and limited time available. This phenomenon was more apparent within the two groups of Master’s students than the group of researchers, for the reasons discussed above. Furthermore, the ways in which the CDEs were presented varied from simple sketches to more detailed concept drawings and verbal presentations. The researchers produced relatively refined visualisations whereas the students presented sketches that were generally quite simple, again for the reasons discussed above.

With regard to the oral presentation of the CDEs, the students generally communicated their concepts in a way that reflected the time spent on developing them, i.e. simple black and white sketches and a few sentences. It is perhaps the case that the relatively short time allotted to the groups for developing their ideas meant that the presentations were as important for the learning outcomes of the participants as the element of actually creating their ideas. In other words, the oral presentations gave those who had not yet (fully) understood the concept a second chance – and, based on the murmurs of “aha!” that were heard during the presentations, principally expressed by the Master’s students, this aspect of the workshop was strongly appreciated. It is often said in pedagogical contexts that “the whole is greater than the sum of its parts” (Burke, 2011) – a phrase supposedly coined by Aristotle, and one that suggests that the practice of presenting was valuable and worthy of inclusion in future workshops.

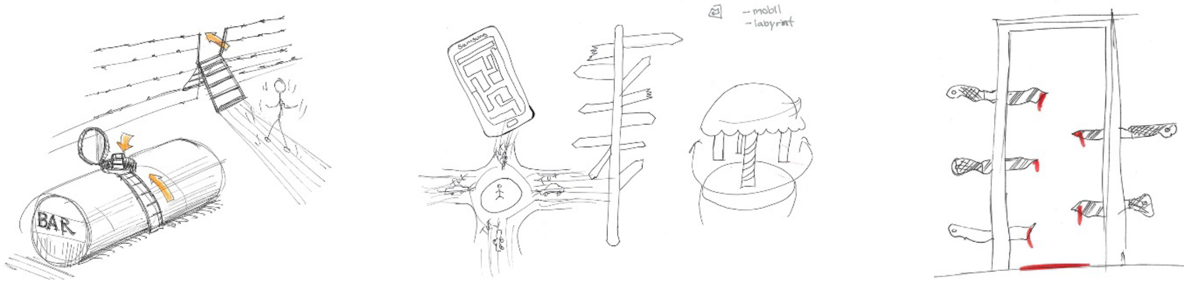

Figure 4. Examples of the CDEs that were created during WS2. From (top) left to right: A staircase, with a mandatory 'spinning drum stop' in front, so that every person entering the building is equally off-balance; various 'orientation-devices' to make users walk in circles; a door entrance that punishes those who do not walk straight when passing through it (Torkildsby, 2017).

6 DISCUSSION AND CONSIDERATIONS

This paper has presented the CDM and discussed how it can be implemented in design processes to expose assumptions, generate interesting questions, and discover new ideas. Incorporating this way of thinking into design education programmes would provide students with greater insight into what it means to be human in the physical environment and, more importantly, what might happen if they – the next generation of designers – do not take into account this aspect of designing. Furthermore, critical design methodologies, be they in the form of the three-step approach used in WS1 or the fictional settings of WS2, encouraged students (and, on one occasion, a group of researchers) to think outside the box – to not simply engage in 'affirmative design', i.e. design that "reinforces how things are now, [how] it conforms to cultural, social, technical, and economic expectations" (Dunne & Raby, 2001). As Einstein once allegedly stated: "The significant problems we face cannot be solved at the same level of thinking we were at when we created them" (Nolet, 2016, p. 80). Hence, it is not outrageous to say that the CDM is likely to be a good contribution to the field of UD as both a method of teaching and learning and a means of practicing UD further down the road, when students have stepped into the real world and will have to deal with the concept at some point in their careers. As Galloway argues: "Since facts seem to end debates, and design seems to open them up, our greatest chance for critical invention arise [sic] in our engagement of shared concern – even if that means we cannot solve a problem" (Malpass, 2017, p. 131; cf. Galloway, 2007). Thus, the CDM is in line with contemporary design thinking, even though it aims to find problems rather than solve them.

More workshops in educational contexts – primarily within creative disciplines such as design and architecture, and preferably lasting two or more days – need to be held in order to see the whole picture. The discussions in plenum that followed each day of WS2 revealed that some of the scenarios given to the participants were felt to be too specific, making it difficult to truly 'design for all' rather than for a specific individual (this was particularly true for those scenarios that involved personal assistive technologies). This was very useful feedback as regards revising the content and structure of future workshops, which could begin with the participants creating fictional settings based on Steinfeld and Maisel's 'Eight Goals of Universal Design'; body fit, comfort, awareness, understanding, wellness, social integration, personalisation, and cultural appropriateness (Steinfeld & Maisel, 2012). These could then be developed into suitable CDEs, and in so doing the participants would gain valuable experience of developing fictional settings (fictional people and environments), drawing on Grudin and Pruitt's "personae" which, when used correctly, constitute a powerful design tool (2003, p. 1-15). Moreover, they would obtain insight *to* and practise *of* utilising theory in practice.

An alternative approach would be to take a step back and implement both the EDA and the CDM of WS1, although this would require the participants of workshops to be design students, which would mean losing the feedback of others. The eleven workshops and roughly 110 participants show that, regardless of background (be it textile design, industrial design, or occupational therapy), there is always something to be learned from the 'dark side' of design thinking. This is particularly true as regards the ways in which it challenges assumptions and preconceived ideas about the role of the physical environment, in the form of housing, products, transportation systems, parks, and so on, in people's everyday lives. Thus, WS3, which will take place in Belgium over the course of a full week and involve approximately 15 Master's students from the disciplines of architecture, interior architecture, product development, heritage studies, and urbanism and spatial planning is currently being planned (University of Antwerp, 2018). It will draw on the experiences of the previous workshops and lay the groundwork for those that will come after.

7 (IN PLACE OF A) CONCLUSION

Ultimately, the primary advantage of employing the CDM in design education programmes is that students learn how to think, analyse, and evaluate ideas, concepts, projects, and processes in a critical manner. In that sense, the CDM has many similarities with the 'analysis', 'synthesis', and 'evaluation' categories of Bloom's Taxonomy[4]. A secondary advantage is that the method allows students to temporarily move away from problem solving, focusing on asking questions instead of providing answers – finding problems rather than solving them (Dunne & Raby, 2013, p. vii). In addition, design students are provided with improved knowledge which can be applied to designing products and environments "for the greatest extent of users with heterogeneous abilities" (Zöller & Wartzack, 2017, p. 58). Thus, they have a broader understanding of the user themself as regards quality of life, for example. Furthermore, emotional satisfaction – in addition to the physical and material aspects of well-being – should be a top priority, for example, as a way to fight

[4] These can be described in brief as follows: 'analysis' is critical thinking focused on parts and their functionality in relation to the whole, 'synthesis' is critical thinking focused on putting parts together to form a new and original whole, and 'evaluation' is critical thinking focused on valuing and making judgments based on information. For a more in-depth discussion, see Duron, Limbach, & Waugh, 2005, p. 160.

stigmatisation (Ibid., p. 55). Finally, but most importantly, students obtain hands-on experience of the complications that may arise if this aspect of design – “the ‘dark side’ of design thinking” (Torkildsby, 2014, p. 20) – is ignored. By turning pedagogy upside down, a new approach to teaching and learning about design is born.

Consider an increasingly multicultural world, shaped by humanitarian crises and the migration of people, and the fact that the population of 60-year-olds of this world will have doubled from its current level by 2050 (WHO, 2018). Based on this, we can conclude that many new design challenges will appear in the future with regard to our physical environment. These include: a) The difficult task of the housing design of the future, and the fact that it must allow individuals to ‘age in place’; b) sustainability in the sense that everything, including workplaces, must be usable by a broader population; c) social justice, as ‘design for diversity’ as a mantra includes the concept of ‘social justice for all’ (WBDG, 2018). Hence, bringing alternative methods into education – and eventually perhaps into the ways of working of professionals – will likely help UD to develop as a discipline. This, in turn, will better equip designers to meet the needs, wants, and desires of an ever-changing and increasingly complex world, and so evolve as universal design thinkers. According to Malpass, “the [designer] allows for a greater critical manoeuvrability and means of progression into the future” by opening a discourse through critical design practise – which is, of course, complemented with a strong concern for ethics and aesthetics (2017, p. 131). This, then, was the intention behind the CDM workshop series; to emancipate and enlighten the next generation of designers. Moreover, creative and critical thinking must join forces to a greater extent than today in order to, in the words of Mickahail, “bring forth [the] creative innovation and problem-solving ideas needed in the 21st century world” (Mickahail, 2018). Amen, we say.

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23.2

Developing Empathy for Older Users in Undergraduate Design Students

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Abstract

Empathy has been recognised as a key skill by practicing designers. With rapid changes to inclusivity and accessibility in the transport sector, student designers need to appreciate and understand the way in which people of differing abilities are able to engage with and interact with transport. They need to not only develop an understanding of older and vulnerable users - how they experience products, vehicles, services and systems - but also have the confidence to try out new ways of finding information and gaining 'authentic experiences' to feed into their designs. Although empathic design is encouraged, there is often little opportunity for this to occur in a full educational curriculum.

To meet this need, the authors are developing a framework for teaching empathic design using low fidelity, experiential prototypes – using material that is easily available and affordable to design students. This paper reports the first steps towards designing a brief intervention to increase the empathic horizon of transport design students. It concludes with recommendations on how to create high quality learning experiences for students that will enable enhanced empathic design outcomes as they embark upon design careers.

Key words

elders, experiential prototyping, design research, teaching, empathy

Introduction

Empathy is defined as 'the intuitive ability to identify with other people's thoughts and feelings – their motivations, emotional and mental models, values, priorities, preferences, and inner conflicts' (McDonagh, 2008). It is distinguished as *feeling with someone,* rather than *feeling for someone*. Thus, in a fast-developing empathy economy, users search for deeper meaning from their material objects, and functional needs must be enhanced by meeting the ephemeral emotional needs of users (McDonagh 2017).

This poses a problem for young designers, who may lack the experience, knowledge, confidence and (even) interest to design for those who are unlike themselves. Therefore, there is a potential gap between the skills which graduates possess and the needs of industry. Koskinen et al., (2003) concluded that designers need empathy and that this requires making an emotional connection with the user, understanding their situation and why certain experiences are meaningful to them. It is often lamented that there are few opportunities within industry to have 'continual informal encounters with users' (Postma, Zwartkruis-Pelgrim, Daemen & Du, 2012), and this lack is reflected within design education.

As a consequence, a more qualitative approach is needed to inform and inspire designers, to help them understand the personal experience and private context of the 'other' (Mattelmäki et al., 2002; Fulton 2003). This could come about through a number of ways e.g. immersion in the life of the users, design probes, imaginative projection (Fulton 2003; Koskinen and Battarbee 2003). As Battarbee (2004) stressed - the willingness of designers to engage in empathic experiences is key.

In this research, we are looking at ways to provide opportunities for students to build up their knowledge and understanding of people who are different from themselves within course structures. If successful, an empathic design experience can expand students' 'empathic horizon' - used to indicate the limits on a designer's individual ability to empathise beyond certain characteristics of his or her group, such as nationality, background, age, gender, culture, experience and education (McDonagh-Philp and Denton 1999). This can change and develop over time, for example, through training and experience. We want to provide students with the confidence to look at more experiential ways of understanding 'the other' (in this case older people and those with disability) and a set of 'quick and dirty' techniques they can apply in their design work.

Design students typically tend to perceive user engagement experiences/exercises as valuable but are ultimately keen to get back to core design activities such as sketching, concept generation and model making. Therefore, simply providing an empathic design experience is not enough. This will provide students with experience and may help them to empathise with users, but they need to also reflect, communicate and act upon this improved understanding. Consequently, experiential simulations need to be scaffolded within a reflective cycle (Schön 1987) which enables knowledge and meaning to be extracted from encounters and influence design.

Developing a framework to increase the empathic horizon of undergraduate design students

Collins English dictionary defines a framework 'as a particular set of rules, ideas, or beliefs which you use in order to deal with problems or to decide what to do' (2017). The main aim of our project is to develop methods which can be sued to increase the empathic horizon of designers especially in relation to older and disabled users. There are three classes of tools that can promote empathy in designers (Kooprie and Visser, 2009):

1. Techniques for direct contact between designers and users (research). Whilst it would be extremely beneficial to bring students into contact with real users, in practice the research skills and sampling accuracy needed to undertake meaningful and useful research in undergraduate study may limit this approach, unless the student displays tenacity and commitment to targeting representative users with high quality research instruments. Observational, codesign and living lab models hold further potential. McDonagh runs a course called 'Disability + Relevant Design' which specifically integrates students with disabilities (non-design students), design students with disabilities and design students without disabilities. The course generates an environment of heightened understanding of 'difference' by acknowledging how different lived experiences can significantly impact innovative problem solving. The aim is to design more empathically for all, whilst being guided by those with a different life experience. This course has supported a blind graduate in Industrial Design and an undergraduate student who is a wheel chair user. Not only is design opening up for people with disabilities, it is sensitising design students without disabilities to respect and collaborate with non-traditional life experts to enrich their design outcomes.

2. Techniques for communicating findings of user studies to design teams (communication). Here, experienced researchers and design teams conduct the study, interpret and communicate the user data and findings. This has been advocated as a way to let designers understand the experiences of the user. In this context, the emphasis is not on quantitative data, but on storytelling (e.g. van der Lelie, 2005). Again, it is recognised that there are few opportunities within a design curriculum to facilitate this due to time and resource constraints. Additionally, if there is not direct connection between the research and the students' current projects or interests this may fail to spark interest or imagination.

3. Techniques for evoking the designer's own experiences in a domain relevant to the user (ideation), with designers trying to simulate the user's condition through ideation. In relation to this, a technique which is gaining attention is the use of whole-body simulation suits in design and transport research to provide designers with an immersive empathic experience [e.g. Schmidt and Kekel 2013; and Armstrong, Stone, Immel & Hunter-Zaworski, 2013). Any type of representation designed to understand, explore or communicate what it might be like to engage with the product, space or system has been described as 'experience prototyping' (Buchenau and Fulton Suri, 2000). Focusing on situations allows the designer new insights; rather than looking at user characteristics, they can focus on behavioural or experiential aspects. This technique seems most appropriate for building a framework to increase the empathic horizon of design students who are unlikely to have extensive opportunity to engage and study others in their training.

For this project, we focused on ideation, using a framework based loosely around that of Kouprie and Visser (2009) including stages: 1) discovery, 2) immersion, 3) connection and 4) detachment to which we have added the pre-stage of receptivity (following Battarbee, 2004 and our own experiences (below)).

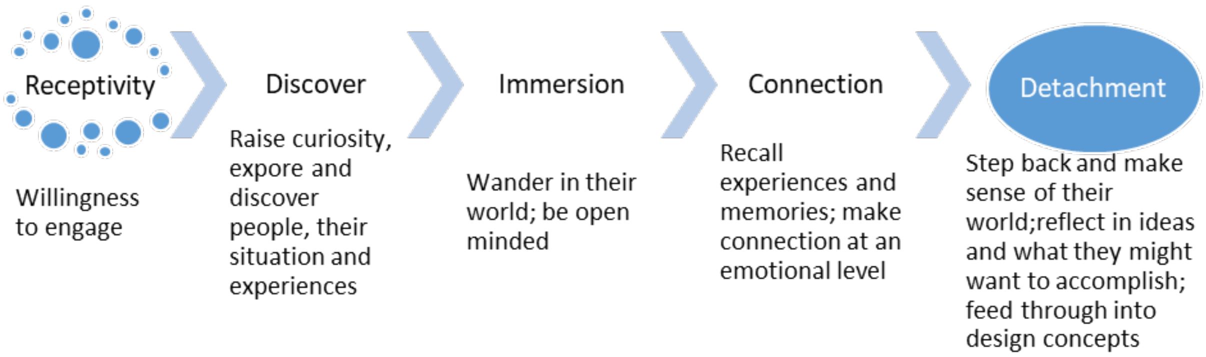

***Figure 1: Empathy framework** Kouprie and Visser (2009)*

To support this we have applied Schon's (1987) principles of reflection in, on and through action to encourage students to think more deeply before, during and after their experiential simulations. Time was allowed after each experience for students to verbalise their personal reflection to the group: what they experienced, how they felt, what was different, and how this could relate to their current and future design activities. This was conducted in a structured way – through 'quick writes and with targeted questions supported by group tutorials designed to enable students to share the problems of different disabilities.

The following section provides an account of the way in which we implemented our framework with a small cohort of final year, UK undergraduate design students.

Implementation

University students tend to have excelled academically to ensure a place on a degree programme. Within the field of design they tend to have excelled in fine art (e.g. painting, drawing) and the craft areas (e.g. ceramics, furniture). The educational experience at university tends to focus on building and developing abilities and skills. This exercise deliberately reduced their abilities and impaired them for the first time as young adults. For young student designers, diminishing their abilities even slightly can have a dramatic impact upon them. The realisation that others may struggle at activities of everyday living becomes a 'felt' realisation.

Following ethical review and consultation with final year tutors it was agreed that we could offer our empathic design intervention as an optional element for students undertaking their final year project. Students could elect to work with us, and in so doing would be provided with extra research material, tutorial support and opportunities to engage in low fidelity simulation of disability and old age. In return they would be eligible for financial support with model making, IP (where appropriate) and prizes on submission of their final project. The authors made themselves available for tutorials at two weekly intervals, providing additional support with integrating empathic design into the final year project. In addition, social media resources and a web site were provided for students to share and exchange experiences, insights and materials. In this way it was hoped to create an online repository, which would also include ‘talking heads’ of older people.

The stages were played out with the students as follows:

Receptivity. The whole class (of over 50 students) was introduced to ‘empathy’ with a motivational lecture (delivered by the second author) and the offer of generous financial compensation for volunteers who were willing to use empathic design as a pillar of their final project. Around ten students expressed interest in the programme, even though many were undertaking projects that required knowledge of older or vulnerable users. This was disappointing, but noteworthy. Therefore we have included it as an additional step in our framework.

Discovery. The five volunteer student designers, making up the final cohort, were provided with tutorial support, written material and a small classroom immersive experience to raise their curiosity. Material provided included

- Glasses: simulating a variety of conditions, such as macular degeneration and cataracts
- Ear plugs: to reduce hearing in one or both ears
- Masking tape used to tape thumb and forefinger together on dominant hand, and bind three fingers together on non- dominant hand
- Thin gloves to reduce sensation in hands
- Bandages to restrict movement

This involved them trying to read labels/open packages and eat with reduced vision, hearing, mobility and tactile impairments. They further explored this in their home environment. Uploading photos and sharing experiences reinforced group cohesion and added new insights.

Immersion. Typically at this stage the designer moves out of his/her office and explores the user’s world. As the focus of the project was the design of transport for ageing populations, students took part in a ‘walkabout’ where they were required to perform all activities involved in travelling from the university to the main rail station, boarding a train to a local station and returning. To support this ‘experience prototyping’, low fidelity simulations were used, including a range of visual impairment glasses (to simulate glaucoma, macular degeneration and cataracts), mobility impairments (crutches, wheelchair, tape to stiffen legs) and hearing loss. A companion looked after the students and videoed significant moments. On arrival at the destination, students took on another simulation so they experienced different or multiple disabilities.

Connection. This was achieved in the debrief sessions. Students were given ‘quick note’ sheets to record their thoughts before, during and after the experience. They were required to upload and share their videos and talk about their experiences in a group tutorial. Here the student was required to connect with the user by remembering experiences and what it felt like to be in that position.

Detachment. This involves the student stepping back into the role of designer, to deploy the new insights into the current design task. As this exercise occurred half way through the design project, it could not shape the initial design. Instead, students were prompted to comment and show how their initial design thinking and concept designs would change as a result of their experiences, for example by placing more attention on visual cues for ingress and egress of vehicles, and look at the overall customer experience of getting on to train.

Experiencing the experience of another experience

This section describes some of the students' activities and reports in the discovery, immersion and connection stages of the framework.

Discovery

Students were prompted to talk about the problems they experienced as a group and circumstances in which they had felt 'disabled' e.g. when they had broken limbs or were in new cities. Following this they were encouraged to take the material home and try to do everyday tasks in their home environment and share experiences on social media.

Figures 2 and 3: Low fidelity prototyping in the classroom

Immersion

Using low fidelity simulation at home

Following their initial experiential simulation in the classroom, the students were asked to take materials away and experiment on their own to see how impairments might impact on everyday activities. They took the opportunity to explore how different, familiar everyday tasks felt when having restricted vision and mobility, such as making a drink, using the television remote control and getting into and out of a car. The following images are courtesy of one of the students, who restricted his hearing, using earbuds to simulate deafness and tape to restrict movement in his hands and knees (approximating mobility restrictions in arthritis).

Figure 4: Using everyday materials to restrict mobility and hearing

He then created a story board relating to the problems he had experienced to inform his own practice and communicate this to the rest of the group. In this case he was simulating how to put shopping in the boot of a car and get into the driving seat.

1. Approaching the car with shopping required a lot of concentration to not drop the shopping bag with reduced strength, mobility and dexterity in the preferred hand.
2. Finding and using the car key. The key was difficult to grasp and pull from the trouser pocket. The restrictions in mobility meant that both hands had to be used to press the button on the key. This was difficult while carrying shopping.

Figure 5 and 6: Approaching the car

3. Putting shopping in the car. Opening the boot was difficult owing to restricted movement in the hand made it difficult to squeeze the handle to lift up the boot. Narrow space between the two cars was difficult to manoeuvre in, with restrictions in flexibility of the knees. Putting the shopping in the car would also have required a lot of twisting which would have also been hard for older people.
4. Closing the boot. Limited dexterity caused the task to be more difficult and required a lot more time and focus than normal.

Figure 7: Using the boot with reduced dexterity

5. Getting into the car. The student had simulated having limited mobility and stiffness in his legs, reduced sensitivity and dexterity in his hands. Reducing the ability to hear meant that he was unable to fully attend to the road environment, and as such was not aware when cares were approaching, which was an unforeseen hazard. The reductions in dexterity prevented the tasks from being completed in the normal way. Issues shown below related to opening the car, getting into the car and closing the door with one hand.

Figure 8: Getting into the car

He concluded that:

“this was a mountain of a task, it made multitasking very difficult and delayed every task – the whole think took double the time, I became more frustrated as it went on and I even thought about not bothering. This is not an option if you’re having to travel somewhere important. I tried to do the task how I normally do it and it was just not possible…..In some cases I was in real danger as I heavily rely on my hearing – something I had not noticed before. But I did not really check for vehicles coming as I’m just so used to listening out for them… The task made me realise that if I were to design for those who are not as abled, things really do need to function well, not just look aesthetically pleasing. The experience needs to be easy and comfortable, not a mission.’

Immersion in the real world

The following figures illustrate three distinct student experiences while conducting empathic modelling. Figure 7captures a student wearing glasses that simulate Retinosa Pigmentosa (e.g. tunnel vision) while traveling across the city via train. The first image illustrates the glasses. The second image shows her engaging with the ticket machine interface, which she finds too demanding and resorts to seeking help from a member of the station staff (third image). The final image illustrates how close she needs to place the ticket to her eyes in order to read it.

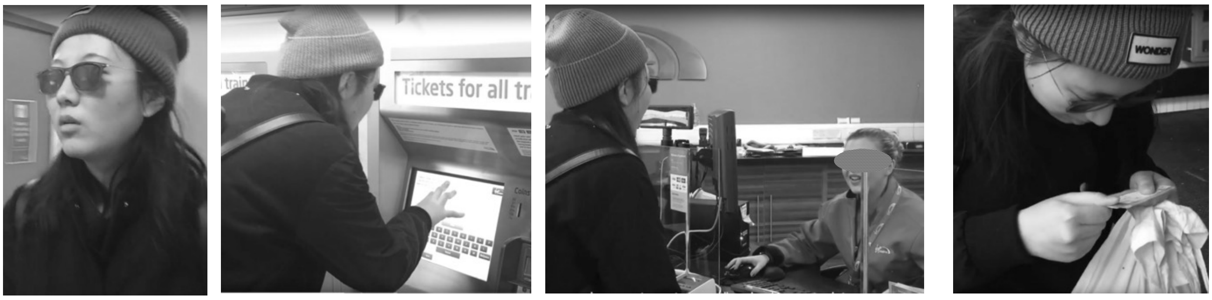

Figure 7: Student wearing empathic glasses that simulate Retinosa Pigmentosa.

Figure 8 introduces a manual wheelchair. The student is captured crossing a road, descending a pavement/curb cut, crossing the road and then ascending the payment/curb on the other side (left). The student felt vulnerable during this activity. The second student, again in a manual wheelchair is also wearing empathic glasses (simulating visual impairment) and using a public toilet/restroom. He can be seen washing his hands, with his arms stretched out straight and using the hand dryer. What is important when experiencing a manual chair is the physical effort required to push the wheels and the eye level that this chair affords the user. As abled bodied tall males, they experience a reduce stature.

Figure 8: Student experiencing a manual wheelchair (left) and wearing impairment glasses while using a manual wheelchair.

Student responses

The students engaged with this study provided the following insights from their personal experience of empathic modelling:

Difficulty: The students found the modelling much more difficult than anticipated - while they were used to developing personas and characterising ‘older and vulnerable users’, experiencing disabilities first hand seemed to come as a ‘shock’.

> “I thought it wouldn’t be that difficult.”

Vulnerability: Students were unaccustomed to feeling vulnerable in a way that a physical impairment made them feel.

> “I felt so inadequate, frustrated and scared”;
>
> “Felt everyone was watching me and judging me”;
>
> “I felt so incredibly self-conscious and uncomfortable.”

Cultural imprints: Culture issues came to the surface.

> “It caused a fuss. Being British no one likes a fuss.”

Normality: The process was also described as disruptive.

> “Disruption from normality.”

Non-verbal cues: The impaired vision/hearing was also described as restricting situational understanding, which made them feel very vulnerable.

> “I couldn’t read peoples’ faces… or their intentions.”

Connection

Table 1 summarises the responses of the student to travelling with a disability and their companion. The companion not only ensured that the student was safe, but could also record the problems the student experienced and add their own reflections. In this way, even students who did not wish to fully engage with project could benefit. These reflect the comments in the previous section.

The students reported embarrassment at being too slow or a hindrance when they could not interact quickly enough to buy bus tickets, they felt isolated and scared when they were not able to see people clearly or read their facial expressions. They started to become sensitized to the problems others would have. Some of the views also reflected a weakness of this approach. The students felt self-conscious. They did not have a disability, but were ‘dressing up’. This led to some embarrassment.

Table 1: Example of student responses to the experiential simulation walkabout

Student and simulation	Thoughts before activity	Thoughts during activity	Thoughts after activity
Male sight impaired	• Nervous after doing something like this before • Confident in my abilities still	• Majority of the time felt self aware and that people were watching • Struggled with depth perception • Frustrated	• Relieved that it was over • Surprised how much I struggled without sight • Helped having bright colours to see steps • Felt nervous all the time • Always planning ahead
Male helper with sight impaired student	• Interesting to find out how difficult it is to access public transport whilst being impaired • How can PT be improved to accommodate disabled users in the future	• Very stressful, hard to see things such as door handles, screens and people • Had to take a lot more time to think about what to do in the most simplest of tasks • Really struggled to co-ordinate	• Contrasting bright colours would help a lot to distinguish between different surfaces e.g. door handles and door cards • Relieved to have my sight back
Male student with crutches	• May be a struggle when getting into a black cab • Crutches will be a struggle when walking though the train [sic]	• Very vulnerable and self conscious of other people's views on somebody with a (simulating a) disability • Very tiring • Easy to get lost without any help from other people • Stressful on the wrist	• Disability ramps at station were too long • Bridge seemed too high, no lifts • Bus had no announcements – had to guess when to get off • Lack of signage and illegible signage to those with eye issues was tricky
Male wheelchair user with hearing impairment	• May not be able to use the wheelchair with the train • Wheelchair could be tiring • Hearing impairment is new to me, not sure what to expect	• Really difficult to use the wheelchair by myself • Poor hearing – less inclined to conversation	• Hearing impairment not a great issue • Couldn't use the wheelchair on my own for more than a couple of minutes • Everybody very helpful

In summary, the students found that moving through public space with impairment was difficult. Specific issues raised included the length of ramps, difficulties using (seeing) ticket machines, finding lifts and signs, navigating stairs, crossing the road safely. Additionally, students felt vulnerable and fatigued even after a two-hour session. They were relieved to be able to 'shed their disabilities' at the end of the session and commented that they would not feel confident enough to go out alone with their particular disabilities.

Evidence from student comments suggested that their empathic horizon might have changed. They had more insights into why someone walked more slowly, needed support, was unsure where to go, which appeared to translate out of the classroom, and helped them gain new insights into 'how the world actually worked' for people with mobility issues. Additionally this new understanding was reflected in changes to their final designs, which reflected a greater sensitivity to the needs of their end users.

What makes a good empathic design experience for students?

Empathic design refers to design solutions (e.g. products, services and environments) that satisfy functional and emotional needs of users (customers and/or consumers). Designing a solution without taking into consideration needs beyond the functional (e.g. neglecting the emotional, cultural or social needs) could reduce the effectiveness of the solution from the user's perspective (regardless of how functional it is). The strength of empathic design lies in its raising awareness of 'what makes life rich, personal and meaningful'. Empathic designers need to be able to reflect on and use their experiences to inform their own design and be able to communicate that to other team members. The framework we are building aims to enable student designers to develop these empathic skills, in order to ensure more effective design solutions.

We have demonstrated that the 'real life' experience of disabilities can embed the needs of those with mobility problems within the student thinking process, in a way that may not be replicated by more distant research methods (i.e. reading, observing). Certainly, the students who took part evidenced a sense of shock at how difficult it had been to navigate through their everyday world with an impairment. Despite the shocks the students experienced, the walkabout was also described as fun and relevant to their studies.

Thus, although the students experienced discomfort, vulnerability and frustration, overall this type of learning experience is more likely to 'stick'. This 'sticking experience' could possibly indicate that for design students, empathy is a 'threshold concept', characterized as 'akin to a portal, opening up a new and previously inaccessible way of thinking about something. [It] represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. As a consequence of comprehending a threshold concept there may thus be a transformed internal view of subject matter, subject landscape, or even world view' (Meyer and

Land 2003). This would build upon an emerging thread identified by Osmond in previous research with design students (Osmond et al 2008; Osmond and Mackie 2012).

Students have the luxury of choosing design projects, the design decisions of which should be based on research. First hand research (e.g. through observations, field studies or modelling) whilst difficult to organize with large cohorts may have more long-term value than those, which simply survey classmates and university staff.

Consequently, a good empathic design experience should allow students not only to experience and empathise, but also to reflect, communicate and act upon their improved understanding. Clearly, without a user panel associated with a design course this is difficult. Opportunities should be provided within course structures or students to engage on voluntary work (e.g. helping the community) to build up knowledge of users who are different from themselves. However, such encounters need to allow time for reflection in, on and through research (Schön 1987) which enables knowledge and meaning to be extracted from encounters and influence design.

Meanwhile, for future design projects, it is more likely that they will consider the needs of both current and future users in a way they would not have without this activity. It is hoped that this will become embedded in their thinking, to the point that building in additional functionality (improving ease of use and anticipating users' needs) becomes part and parcel of their design outcomes, regardless of whether the client specifically requested such sensitivity to the users.

Conclusions

Disappointingly few students were motivated to take part in this study even though it was directly relevant to their projects and the advantages of showing empathic awareness as an employability differentiator were pointed out to them. Additionally, there was a strong sense that the students felt that technological and medical advances would solve the problems associated with mobility in the next 20 years, for example, autonomous vehicles and virtual reality displays. Ultimately their final award needed to demonstrate design skills above user awareness and understanding.

There was some drop out and non-attendance amongst our small cohort owing to conflicting timetabling which meant we were not able to develop a strong, enthusiastic group. The project did require a time commitment on the part of the students and the authors of this paper. On average 4 hours a month were required by all participants to maintain levels of commitment, motivation and guarantee the usefulness of this study, outside of normal activities.

However, despite the low student attendance, those that did take part found that they were surprised by the experiences – as young undergraduate students they were all able bodied and not accustomed to not being able to navigate quickly and efficiently through public spaces. This was particularly evident by their feedback, which showed that they felt more vulnerable than they usually did and also reflected a degree of heightened self-consciousness. This, it could be argued, reflects the general view of vulnerable users as 'other' – who as a perceived small minority - have needs that are routinely not considered in design activities. The students demonstrated the value of experience in their stated willingness to use modelling for future projects, and embed some of what they learnt into their existing project.

The materials gathered will form part of a growing online repository of video experiences, storytelling and research papers accessible by future design students that will be comprised of personal user experiences from around the world.

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23.2

Older Adult Insights for Age Friendly Environments, Products and Service Systems

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Abstract

The environments we grow old in present a challenge to be adaptive to our changing needs and limitations. Environments, in the context of this paper, are the spaces, products and product service systems that we engage with, alone or with others, within and outside the home. A design coalition (Manzini, 2015) was generated between a number of academic Institutions and ISAX (Ireland Smart Ageing Exchange) an 'ageing think tank' organisation in Ireland. The intention of this coalition was to generate awareness of needs requirements for age friendly environments and to provide an example of how participatory design research can inform innovation in business and policy development at a local and state level.

A five-week study was conducted using design and ethnographic methods with twenty-two older adult participants (age range 69 – 80). The themes of study were identified as: mobility, public spaces, safety, social engagement, services & facilities. Cultural probes, semi-structured interviews and user observation, by both researchers and older adult participants, were used as methods to identify the unmet needs of participants within the sample group.

A Co-Design Symposium (http://info.isax.ie/national-co-design-symposium) was held during June 2016 as an opportunity to demonstrate to a wider stakeholder audience the needs identified from this study. This Symposium was attended by over 100 people of various backgrounds (town planners, architects, transport experts, retailers, builders, health and other service providers). The older adult participants and designers (staff and researchers from the School of Design at the University of Limerick, IT Carlow, Limerick Institute of Technology and Limerick School of Art & Design) were placed within teams of ten. The research was presented using audio/visual

presentation as well as artefacts from the fieldwork, completed diaries, scrapbooks, storyboards etc. Solutions were worked on, and delivered at the end of the day. This Symposium has impacted positively whereby policy makers in local government have invited ISAX to further discuss research outcomes and the needs of older adults as a means to develop access areas in and around Limerick City. This paper outlines in further detail the design research methods used, and the benefits through design education Student/ Researcher /Stakeholder collaboration by application 'in the 'field' and displays the effectiveness of design coalitions in influencing and affecting change and insight into policy. It highlights how co-design collaborations can impact and generate design solutions that improve day to day experiences.

1: Introduction

There are a number of age specific agencies focusing on the needs identification and mobilization of the older adults' voice as a means to influence and deliver product and service systems that benefit all. One such agency is ISAX (the Ireland Smart Ageing Exchange). As a result of a rapidly growing ageing population and an increase in longevity, everyone who lives long enough will experience a disability, or a gradual decline in physical, sensory or mental abilities (Morris, Mueller & Jones, 2010). The ageing population is a design concern that requires ensuring that design in industry, and higher-level design education, generate awareness by engaging with older adults using participatory or co-design methods. As design becomes more embedded in society new practices are emerging (Broadbent & Cross, 2003). Emerging design practices, centre around people's needs or societal needs, and require a different approach in that they need to take longer views and address larger scopes of inquiry (Sanders and Stappers, 2008). To elicit their user knowledge and to better understand the context of user experience, the active participation of potential users in the early stages of design process has gained importance (Sleeswijk Visser, 2009, Turhan & Doğan, 2017).

A collaborative coalition of academic institutions, (University of Limerick, Institute of Technology Carlow & Limerick School of Art and Design, Limerick Institute of Technology) came together with ISAX; with the intention to organize a co-design symposium to exemplify how this activity can affect change and influence policy. Research through design (Frayling, 1993) is an activity that diarises and documents the paths to understanding and defining needs requirements. There is a move from designing for people to designing with people (Sanders & Stappers, 2014). Designers as part of a team are responsible for carrying out research, analysis, and interpretation of data and creating solutions with the stakeholders involved in any given context (Bate & Robert, 2007). Designers can also use the ideas generated by others as sources of inspiration and innovation. Co-design as described by Manzini as a "*social conversation*" was deemed a suitable approach on which to build the collaborations required for the Symposium. Co-design in various forms, from participatory design to co-creation, is growing rapidly. Co-design is not just about being responsive to stakeholders and listening to their needs; stakeholders actively contribute to the design of solutions (Bate & Robert, 2007). Designers and design researchers are exploring the creation of tools that non-designers can use to create their own solutions. Therefore, a variety of stakeholders including older adults collaborated in a symposium to identify needs and develop solutions in a variety of areas. It was agreed that in order to build the structure of a symposium, themes would need to be identified that would offer insights to ageing, and day to day activities and tasks. A strategy to recruit participants, including an ethics approved plan for fieldwork, was devised. Older adult participants, students, researchers and staff from the School of Design, University of Limerick created a collaboration to work together and learn from each other and through each other. This activity, would deliver identified needs statements as the brief for each theme and work for the symposium.

2: Design education

In conducting design research there is also a growing emphasis on ethnographic and observational research. Observing people using products and services can lead to the discovery of unmet and unarticulated needs which can lead to a breakthrough in innovation (Cooper & Evans, 2006). Despite industry advances there is a belief that education is not supporting these opportunities and that design students are not well prepared with the skills for professional practice when they graduate (Kiernan & Ledwith, 2014, Sanders & Stappers, 2014). There are however some moves to include design research methods including generative and participatory design methods and knowledge from the social sciences at undergraduate and postgraduate level (Sanders & Stappers, 2014).

The objective however in introducing any new methods to a curriculum is to also promote a positive learning experience for students. It has been shown that active (McMahon, 2006) and collaborative learning (Entwistle, 2000) can lead to deep learning by encouraging critical reflection (Entwistle, 2000; McMahon, 2006). A peer to peer and group based learning environment is additionally recognised within design education. Symposiums and workshops can also go beyond the traditional learning model, with limited surface learning, to a transformational learning experience of deep learning. Symposiums and workshops can enable students to relate to the content personally fostering deep learning through personalisation and critical thinking (Watkins, 2014).

2: Methods

In user-centred design, many approaches can be undertaken that involve user influence and activity to inform design, namely participatory design (Sanders & Stappers, 2008), universal design (Story, Mueller & Mace, 1998), co-design (Manzini, 2015). there is widespread recognition for the importance of designers to gain empathy with the users for whom they are designing (Kouprie & Visser, 2009). This involves designers becoming immersed in the lives, environments, attitudes, experiences and dreams of potential users and understanding their needs (Battarbee, 2004). This article describes two stages to participatory design project, 1) fieldwork with older adult participants, 2) a co-design symposium with a wide variety of stakeholders. A five-week study was conducted using design and ethnographic methods (Blomberg, Giacomi, Mosher & Swenton-Wall, 1993; Salvador, Bell & Anderson, 1999) with twenty-two Older Adult participants (age range 69 – 80).

2.1: Fieldwork

The themes identified by the coalition to pursue in the fieldwork were: mobility, public spaces, safety, social engagement, and services & facilities. The fieldwork began in April 2016 and continued over a period of five weeks. At this point the researcher was joined by an undergraduate student of Product Design & Technology in University of Limerick who was working on a Faculty scholarship. The role of the student was to learn through experience of fieldwork by accompanying the researcher and engaging with the older adult participants in their homes, and while on task observation studies. During this time, the following qualitative methods were used, informal interviews, task observations, and self-observed diarizing by a selection of older adult participants of their world and day to day activities over the course of one week using cultural probe packs. Cultural probes are a design research tool that gives control of data collection to the participant (Burrows, Mitchell & Nicolle, 2015). The probes did not require analysis (Gaver, Dunne & Pacenti, 1999) but offered further opportunity to gain knowledge and insight from the world of the participants.

This facilitated the opportunity by the researcher to become intimately familiar with the day to day tasks and activities undertaken and to observe and understand challenges and pleasures experienced by the participants in their worlds. The researcher pursued enquiry with a tacit knowledge that was enhanced further by the narrative shared by the participants during the fieldwork. A template was developed for the interview sessions, the format of which would be loosely structured. (See attachment) This template was used as a tool to memo and add notes or sketches during the interviews. The template details information regarding the participant and their 'ref' anonymity. It also consists of open spaces for memo taking and sketching. The headings are listed with some reflective keywords in brackets - the purpose of this is to allow the participant to lead the conversation, however the researcher can introduce keywords of association to prompt or seek expression and opinions.

As a means to display credibility, integrity and rigour, both to older adult potential participants and other stakeholders, ethics approval for the research was sought and approved through the normal ethics procedure of University of Limerick. This enabled an action plan to present to groups and individuals, and an invitation to participate in field studies. The criteria for participants were: participants aged over 65, living in the Limerick environs, who were deemed independent and living in the community. One of the opening questions to each of the participants in addition to the typical age, home type etc., was "are you active?" Interestingly this was a good conversation opener; 100% of the participants in both groups answered yes, and proceeded to list activities and interests they pursued. The pool of participants was twenty-two older Adults, as displayed in Figure 1.

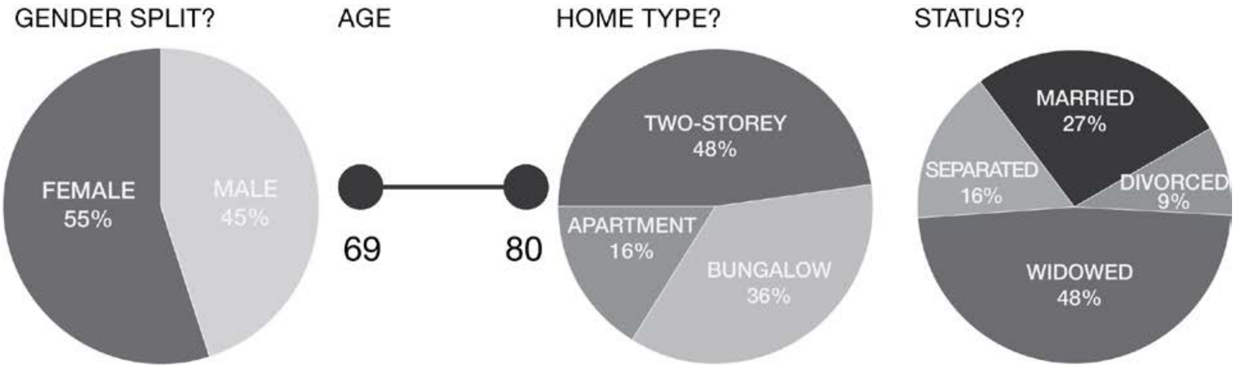

Figure 1. statistical breakdown of participants.

The participants were split into two groups of eleven, with Group One agreeing to be interviewed and observed undertaking various daily activities and tasks. Group Two were briefed, and issued with cultural probe packs that would be left with the participants for the course of a week. These participants would diarize and record items or experiences of interest. The packs were issued in a large wallet, and consisted of the following: 1) A mood board and stickers that the participant could very quickly indicate positive or negative experiences from each day and for each of the themes. 2) A scrapbook and glue stick to place articles, or items read or noticed. 3) A disposable camera to use as they wished for photographic capture and storytelling. 4) A notebook to write and express what went on each day.

Figure 2. Cultural probe pack (left) older adult participant with researcher (right).

During fieldwork, it was important to measure the effectiveness of the experience by the student accompanying the researcher, observations to note were:

- Initially the student was quiet and somewhat unsure of the freedom and flexibility to be curious with the participant.
- By session two, the student grew in confidence and began to enquire and express her curiosity to understand and empathise with the experiences and stories shared by the older adult participants.
- The participants were curious about the student, sometimes they would talk in terms of generational difference, i.e. *in my day...*; *would it be like that now*? There was a warm rapport and interesting exchange between both.

On conclusion of the experience of being out in the field, the student reflected on the work and experience gained, stating:

"At first, I was quite nervous about how to interact with the participants, as I had not conducted any research in this way before. One of the key things I remember from the visits was learning that a conversation is much more valuable than an 'interview'. From watching and listening to Linda I learned a lot about gathering information through gently guided conversation. Without the formality of interview questions and the pressure that they can bring, the participants felt free to direct conversations to the things they felt most passionate or annoyed by."

"I was not lucky enough to know my grandparents very well as an adult. I have incredibly warm and fond memories of them from my childhood, but these are really the only interactions I have had with 'older adults'. Before I became involved with the project, this was not something that I had thought about. In the weeks, I spent speaking and listening to the participants in the study, I realised what a terrible absence that was. Older people, from my experience of the ISAX project, are full of life and a genuine desire to share their knowledge and stories with others. There are many misconceptions about old age out there but the mental strength of the participants I met made me reconsider my 'preconceptions'."

"There were also serious and more sombre conversations, highlighting areas where older adults were not being catered for. Without these conversations, the mix of fun and reality, I would never have considered some of these problems."

This sharing of experiences highlights the impact and valuable learning that can be gained out in the field. When students are attentive to values, meanings and aspirations of those they are designing for, it can contribute to human flourishing (Lynch, 2015). An example of this approach is the Engineering for Humanity course in Olin College of Engineering in Massachusetts. During their first year, students on this programme each work with one older adult participant, and throughout a semester, identify a problem, to develop and build a solution. The older adult participants are recruited from the community and surrounding areas of the campus, the module is described as a *"complete start to finish process of learning to design for a single user*" and this activity, it is believed helps students develop and build meaningful relationships with participants, and an awareness that the solutions can make real difference to people's lives (Lynch, 2015).

2.2: Co-Design Symposium, Limerick, June 2016

Co-design can be considered 'messy', the collaborations of as many stakeholders as possible have input to the design process. This participation, in turn affords an iterative process that encourages autonomy and ownership between stakeholders, with outcomes and intent collectively developed (Donetto, Pierri, Tsianakas & Robert, 2015). The older adult participants offered expert perspectives of their lived experiences (Sanders & Stappers, 2008). The role of the researcher was to gather those insights and translate them to effective needs statements that each group could work with on the day of the symposium. Participants and partners of ISAX were invited to work together for one day on design solutions identified and stated as, '<u>needs statements</u>' for each of the five themes observed during the fieldwork:

1. Mobility – <u>Need</u>: Improvement of accessibility experience outside the home – Bus access, parking, cyclist awareness & pedestrian experience.
2. Public Spaces – <u>Need</u>: Older adults with reduced mobility and their carers require access to busy areas safely, efficiently and conveniently, as a means to conduct everyday tasks and social engagements.
3. Safety – <u>Need</u>: Older adult safety and reassurance when outside the home.
4. Social Engagement – <u>Need</u>: Interaction, support and communication across communities and generations.
5. Services & Facilities – <u>Need</u>: Impartial trustworthy guidance to manage and plan finances and bills in the following areas: banking, general utilities, mobile phone options & estate planning.

Figure 3. Sample of attendees, including older adult, under graduate & post graduate participants from University of Limerick.

To enhance empathic communication, raw data including photos and videos of users in their home and individual stories and quotes have been advocated as a way to let designers make personal connections to the users' experiences (Sleeswijk Visser, Stappers, Van der Lugt & Sanders, 2005; Fulton Suri, 2003; Sleeswijk Visser, Van der Lugt & Stappers, 2007) as how users are visually depicted can promote or hinder empathic understanding (Sleeswijk Visser & Stappers, 2007).

There were various artefacts of research evidence (video displays, storyboards, photographs, diaries etc.) displayed and available for all attendees to view. The research evidence expressed in tangible ways the older adult experiences recorded during the research. Highlighted were various 'joy and pain points'. The 'joy points' ranged from simple things such as well-placed park benches, opportunities for social engagement, volunteering, gardening, friendships and family life. The 'pain points' showed up problems as diverse as a lack of 'set down' areas for cars in Limerick City to 'drop off' a relative, unsafe street crossing areas, car park spaces with limited ambulatory accessibility, tablet blister medication packs that were a challenge to open, and personal security devices that didn't offer reassurance to users.

Participants then worked in teams of ten to build new solutions for these problems, facilitated by design staff and students. Each team focused on one of the themes and comprised of stakeholder attendees, designers (students and staff from School of Design, University of Limerick., Institute of Technology, Carlow, Limerick School of Art & Design) as well as two to three older adults who had been involved in the research. Co-design implies a need for the designer to become the facilitator (Sanders & Stappers, 2008) that encourages creativity by all.

Figure 4. 'Pitch' role-play delivery by group facilitator.

Co-design encourages stakeholders to become part of the design team, and this experience can be enhanced by the provision of the right tools to assist creativity (Sanders & Stappers, 2008) and freedom to express. The teams worked together and availed of tools and discussion to assist and generate ideas. These tools were: modelling tools, whiteboards to map and visualise thinking, artefacts from the fieldwork – diaries, scrapbooks, and large printed boards with summary to each theme. These summary boards encouraged group talk and interactions with other attendees for further discussion, see Figures, 5, 6, 7, 8, & 9.

Figure 5. Modelling tools were accessed and used by all throughout the symposium.

Figure 6. Mapping interactions and relationships on whiteboards.

Figure 7. Contextual tools from the self-observation groups were displayed: scrapbooks with images and diaries with narrative of day to day thoughts by each participant.

Figure 8. Further selection of modelling tools displayed and used to relay narrative and concept development.

Figure 9. Discussion locations were encouraged beyond the tables of each team to encourage interaction, Tools to support commentary are the theme backdrops as displayed in the background of this image.

3: Findings

This section discusses the day's activity outcomes from the concepts produced, in addition, reflections from the experience are shared by a snapshot of attendee and organising students and lecturer. Towards the end of the Symposium, each team was invited to 'pitch' their idea and express the benefits of each design solution. There were ten design solutions offered:

1. Mobility
    - Solution 1: Volunteer Support Service Club

    Create a new membership club, which is aimed at improving access by foot or transport links to commercial or public buildings. The club would engage early retirees, second level transition year students and others interested in volunteering their time, to 'map' good pathways or access links to bus schedules for onward/return journeys by public transport or for car parking spaces.

    - Solution 2 – Improved Car Parking Spaces

    Getting in and out of cars more easily by alternating (L-shaped) car parking spaces, to ensure that car doors can be opened fully, and designing age friendly 'logo' for specific car parking spaces.
2. Public spaces
    - Solution 3 – Designated Drop Off Points

Create ‘drop-off’ points accessed by drivers, dropping off less mobile persons. Each car would have a sticker ID on the windscreen provided by local policy makers. Signs and way finders would ensure the person dropped off is aware of route back to pick-up point.

- Solution 4 – City Ambassadors

Focus on passenger experience with reduced mobility. City ambassadors working within 1km of city centre, near banks, post offices and hotels, to provide support and information at drop-off points and main car parks.

3. Safety

- Solution 5 – Safety in the Home Poster

Design an interactive poster for the home that is linked to a smart device. Buttons will have short cut icons to activate calls to family, emergency services, taxi, and house alarm.

- Solution 6 – Sub-dermal implants

Automatic contact that is always on and is always worn. Sub-dermal implant worn by users for fall or other security alerts.

4. Social Engagement

- Solution 7 – Hands of Friendship Network

This group would engage with new members of communities or areas with older adult population to make new friends and/or re-engage with an area. Building trust, a “Hand of Friendship” group would grow through word of mouth and social activities.

- Solution 8 – Generation Allies

Inter-generational activities through a ‘Generation Hub’ – a community space, to facilitate trust, collaborative learning and laughter. Using ’Generation Allies’ over the lifespan, so that security, respect, health, friendship, advocacy and wisdom can travel in both directions. Suggested tasting event, e.g. BBQ, communal garden. Inform and invite new members using radio, social media and ‘Tell-a-friend’ methods.

5. Services & Facilities

- Solution 9 - Digital Training

Fear of technology is limiting access to online services. Access to a connected device and internet availability are two major issues. The suggestion was that the state offers retirees access to training that will enable people to become digitally literate. Once trained, an incentivised scheme would empower people by providing internet access with a suitable device with apps to access sites such as banking, flight booking and government agencies.

- Solution 10 – Service Navigators

Service system to help people to manage their affairs and provide information that leads to informed decision making, e.g. appointing an executor for a will, putting ‘power of attorney’ in place for future, opening/closing accounts with utility companies. Part of the service would be to provide trusted 'navigators' who can facilitate when needed, e.g. set up a meeting with someone from a utility company, go to medical appointments, or to provide knowledge to assist decision making for major purchase (car). Put a loop system in place to ensure that every service item is managed to its conclusion.

On conclusion of the 'pitch' (figure 10), the attendees were issued with stickers and invited to vote by applying a sticker to their favourite solution. This democratising and validation of opinion led to a clear winning solution; however, the real objective of the day was achieved, a demonstration that cross collaborations between older adults, students, researchers, policy makers and industry stakeholders can deliver efficient and tangible solutions to identified unmet needs.

Figure 10. Older adult participant 'pitching' the benefits of their design solution to attendees.

3.1: Reflections

As a means to learn and understand experience from the perspectives of lecturers, students and stakeholders, involved in the organising and facilitating of the symposium, questions were devised and sent out to gather knowledge and insights. The questions posed were:

1. Prior to attending the co-design symposium, what were your expectations or thoughts to the practice of co-design?
2. During the day, what observations or experiences did you find beneficial to the application of engaging with the various stakeholders and themes of the day?
3. Since the co-design symposium; are there any take-away thoughts or actions that have been inspired, and you have applied to your work – reflections?

To summarise the answers, it is clear that there was an element of anticipation and uncertainty to the day by the answers expressed for Question one. For Question two, there is a certain amount of freedom and passion expressed by the activities undertaken on the day and the interactions with other attendees and participants from the fieldwork. The actions expressed in Question threes answer, endorses the activity of co-design as a collaborative exercise with solutions created and stakeholders involved with designers and design researchers.

Sample responses:

Q1: Prior to attending the co-design symposium, what were your expectations or thoughts to the practice of co-design?

> *"Was nice and ideal in theory, but the practice wasn't always as easy, fluid or productive!"* (Lecturer)

> *"Before attending the co-design symposium, my expectations were based on my experiences in working with clinicians during my own research to inform design decisions. This involved a more solo approach to design in order to generate design milestones, for which the clinicians would then be present to offer guidance and feedback."* (Student)

> *"I was looking forward to taking part in the event, I was interested in seeing how designers interact with users and input from anyone really. I wondered if the designers would take control and dominate the tables."* (Student)

Q2: During the day, what observations or experiences did you find beneficial to the application of engaging with the various stakeholders and themes of the day?

> *"Having the themes and problems set out really helped to focus the projects at the start. Having the older adults present really brought the issues home and trashed my preconceived notions about the limitations (or lack of limitations as I found out) of older adults."* (Lecturer)

> *"Interestingly, and perhaps obviously, dealing with clinicians is much different than working with the stakeholders during the co-design symposium. Clinicians tend to deal with cold hard facts, whereas it was quite refreshing to engage with stakeholders with a sense of empathy. There was also a more conversational approach to informed design too, which was also a stark contrast to the structured feedback sessions I've experienced in the past."* (Student)

> *"Loved the whole day, I thought it was great brainstorming together and getting to know people while doing it. During the event, I noted that one of the moderators, while helping and building the tables as she walked around, was pushing certain solutions to us. I don't think it was intentional but the opinions and biases from organisers is very influential… On the day were we all her 'Users'? At the end of the day, the team I was a part of won the event with the most votes. Our team was the only one which had a user present the work instead of the designers (which every other team did)."* (Student)

Q3: Since the co-design symposium; are there any take-away thoughts or actions that have been inspired, and that you have applied to your work - *reflections*?

> *"I would love to have real-world insights into the users and bring in a co-design process into all of the student projects since but this isn't always possible!" (Lecturer)*
>
> *"I believe that the key take-away experience that inspired me was the enthusiasm of everyone involved. While each group appointed a leader to keep each group on track, there was equal involvement from everyone. No idea was discounted, and there was a great sense of collaboration which culminated in an overwhelmingly positive experience. The symposium has helped me personally by giving me experience into working with people other than clinicians, and perhaps a more accurate reflection of co-design."* (Student)
>
> *"Since then I question, is there a difference between HCD (Human Centred Design) done well and co-design? In practice, it's all about listening to each other and taking part in the co-design event has reinforced that to me. I also believe the role of the designer will still be important when working in these user lead/orientated sessions. A great metaphor I came across which explained this was: the designers and other stakeholders are like an orchestra, each play their part and the designer acts like the conductor which helps keep everyone in sync and flowing together."* (Student)

4: Discussion

The value of collaborations between students, industry, organisations, and in this example, older adult participants, display the effectiveness and impact these kinds of coalitions can influence on product and service system design. Design is a social process and constructivist theories of learning recognize that learning is a social activity (Wenger, 2000; Bucciarelli, 2002). Collaborative and active learning through projects that integrate multidisciplinary specialists and end users is also an approach that better facilitates the solving of today's complex design problems (Seidel & Godfrey, 2005). Design education should be refocused on teaching designers to function in multidisciplinary teams emphasizing the complex process of enquiry, learning and decision-making through working collaboratively using several languages (Dym, Agogino, Eris, Frey & Leifer, 2006). Links with industry and communities to create real-world design projects are crucial to the education of designers (Cardozo et al., 2002; Watkins, 2014). The landscapes of design and design research will continue to change as design and research blur together and designers increasingly co-design with users and stakeholders.

Furthermore, it offers students in higher level education insights to see beyond the studio and gain experiential awareness and empathy for the value of co-design. In a studio-based learning environment the student can be encouraged by the facilitative approach of lecturers. This can motivate the students to become critical thinkers and display an ability to influence and research through design. Kolb's (Kolb, Boyatzis & Mainemelis, 2001) experiential learning model, where knowledge is gained through experience, displays the responsibilities learners (students) have when undertaking this type of project. Design students are further encouraged to have the courage to create (May, 1975) and become self-starters, self-motivated and driven towards sustainable change (Designers Accord, 2011). By encouraging learning beyond the studio and immersion with users as a co-design strategy; minds, curiosity and empathy can be embedded as a subconscious tool. This collaboration paradigm has previously been shown by DeVere, Melles, & Kapoor, (2010) to encourage social responsibility and sustainability among students. It also influences an approach to develop a responsibility to design, delivering projects that can influence real world problems (De Vere et. al. 2010). The co-design symposium is a clear example of what can be achieved when a cross disciplinary approach is undertaken. This is not always addressed through application in a design education context.

An additional benefit through the symposium was in the case of postgraduate students who tend to be most isolated in conducting their individual projects. The symposium afforded them to collaborate with others, refresh their thinking and establish networks bringing additional benefit to their own projects. Suggestions to improve this approach would be to encourage workshops or small studio team based projects. Students would work with a specific cohort through a user based approach to enquire into and explore the unmet needs of daily problems people experience with product and service systems.

A further suggestion would be to undertake a cross disciplinary post graduate program with an industry partner to 'mesh' design through research and collaboration with specific user groups. The objectives of this collaboration would be to identify and define unmet needs in product and service systems. Addressing collaborative practice between Stakeholders encourages the use of co-design and collaborative coalitions to maintain user experience at the centre of the design method.

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23.2

Rescued by Design: Enabling low-resource communities to reduce global drowning

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Abstract

In recent years Bournemouth University (BU) has witnessed a growth in undergraduate projects aimed at resolving problems in low-resource communities, with an emphasis on sustainability through the use of locally-available resources and production methods. BU academics have also been involved in helping the Royal National Lifeboat Institute (RNLI) to develop product solutions to help prevent global drowning, with an initial focus on the Bangladeshi context.

Alongside the potential to enrich or even save lives in the target communities, such projects can offer considerable benefits to a range of domestic stakeholders: from the students and staff themselves to local businesses and non-government organisations (NGO's). But they can also offer considerable challenges - educationally, ethically and practically – including issues with design validation, the reliability and availability of information, and the barriers of differing cultures and languages.

How can educators support low-resource projects successfully? Can students truly gain sufficient understanding of all the relevant issues to design products for an unfamiliar culture, no matter how diverse? And why are low-resource communities looking to designers from the other side of the world to provide low-tech solutions to local problems?

Bournemouth University's low-resource projects have achieved varying degrees of success. By examining some of these - including the RNLI's Bottle Buoy, which has recently gained international acclaim - the authors explore the complex issues relating to the use of such projects in an educational context, and present a proposal for future success using jugaad strategies and greater collaboration.

Key words

drowning, low-resource, RNLI, Bangladesh, Bottle Buoy, jugaad

1 The Global Drowning Problem

The scale of the global drowning problem is huge. The World Health Organisation estimates approximately 372,000 deaths occur worldwide from drowning every year (WHO, 2016). This figure equates to around 70% of the global death toll from malnutrition, and 60% of that from malaria. More than nine-tenths of these deaths occur in Africa and South-East Asia, where drowning is often the leading killer of children over the age of one. Recent media coverage has highlighted the devastating flooding suffered in South Asia during the 2017 monsoon season - which left at least 41 million people affected across the region (Farand, 2017) – but sadly the vast majority of deaths that occur daily from drowning go unreported.

In Bangladesh approximately 50 children drown every day, usually within 20 metres of their home (RNLI, 2017). Communities are often sited close to open water, and they are heavily reliant on local ponds and lakes for daily tasks such as washing and bathing. As there is often no culture of water safety, international aid agencies and non-government organisations (NGO's) have recently been working to reduce drowning by address this. Much of the current thinking and practice in the drowning prevention community involves activity in education, influence, supervision and rescue, but in areas which have seen efficient drowning reduction activity there are still gaps in these approaches. In the UK the Royal National Lifeboat Institute (RNLI) are now increasingly focussing on design and design thinking to further resolve the issue of drowning prevention.

2 LRC Projects at BU

Students attending the BA/BSc Product Design course at Bournemouth University (BU) spend their final year developing a single product in response to a defined real-world problem of their own choosing. Projects relating to low resource communities (LRCs) have been a regular occurrence for many years at BU, with the resulting products invariably intended for industrialised manufacture.

However, there has recently been a notable increase in designs devised by BU students which attempt to enable communities to resolve these issues at a local level, focussing on utilising local resources and production methods rather than imposing western industrialised solutions. Recent examples – primarily aimed at rural communities in Bangladesh and Tanzania - have included a resuscitation training manikin; a playpen (Figure 1); school furniture; and 'man overboard' recovery devices (Figure 2).

Figure 2 ***Figure 2***

This move towards local production has been driven by BU's local links with the RNLI in Poole. The RNLI defines one of its long term strategic goals as to have "effective drowning prevention strategies in place in the highest risk areas internationally" (RNLI, 2015). It aims to do this through a combination of three strategies: building awareness; supporting the adoption of national plans; and providing appropriate intervention and equipment. A part of this final strategy includes the design of equipment suitable for low resource communities.

While the RNLI's own engineering and asset management department have conducted work on suitable projects, it was recognised that issuing live briefs to local students would enable extra capacity for generating solutions. The RNLI supports these briefs by offering access to technical experts and users in target communities, as well as professional test facilities. The RNLI College in Poole provides students with a rare opportunity to test their designs in their world-class Sea Survival Centre which contains a wave tank and lifeboat simulator. In return the RNLI expects students to forego intellectual property rights and allow the release of their designs on an open source basis, thus enabling benefit to the worldwide community.

Some of BU's Design & Engineering academics have also undertaken LRC project collaborations with the RNLI, most recently in helping to develop the 'Bottle Buoy' rescue device. This simple product – initially created with a focus on the Bangladesh context - aims to reduce the incidence of global drowning, and received recent recognition from the International Maritime Rescue Federation by winning the technical category in the 2016 Honouring Excellence in Rescue Operations (HERO) Awards.

While such projects offer a plethora of potential benefits to a wide range of stakeholders – not least the target communities themselves – they also present considerable challenges. The authors gathered feedback from students and members of staff at BU and the RNLI as well as examining previous research and recent developments in design thinking and innovation. By drawing on these different sources, this paper aims to examine the problems and benefits of low resource design projects, and presents potential pathways for success in this field.

3 The Benefits

3.1 Educational stakeholders

Of course, the primary purpose for enabling such projects must be to benefit the student. In common with non-LRC design projects, the process should aim to expand the student's horizons, deepen their subject-specific understanding and broaden their skill base and experience, with the ultimate objective of enhancing their employability (Bournemouth University, 2017). In addition to this, however, LRC projects can include further educational benefits to the student. Schaber's (2010) case study of University of Northampton's undergraduate project to design breadline shoes for Indian children stresses the benefit of exposing students to "socially responsible design and resourcefulness" in the face of severe cost/material/production limitations. The value of involvement in a real-world project with such life-changing opportunities is hugely attractive and beneficial to students, and this was recognised by our research correspondents who agreed that the experience of working alongside the RNLI was particularly rewarding.

As well as students, academic and technical staff also stand to gain from LRC projects. They offer a valuable opportunity to engage in real-world projects with commercial and international dimensions, and can help academics to build relationships with subject matter experts and organisations. They also raise awareness of current issues among staff, and the specialist knowledge garnered by students can filter through to academic supervisors to inform future projects.

Institutions can also reap many other benefits alongside the professional development of staff. BU's RNLI/Bottle Buoy collaboration enhanced the research profile of the faculty, improved the global profile of the University, and earned valuable and widespread publicity as a result of success at the IMRF Awards. BU's student LRC projects have regularly attracted attention at the annual New Designers exhibition in London, as well as the University's own Festival of Design and Innovation. The influence even extends to finances: BU is currently investigating the possibility of drawing on the potential benefits offered by the RNLI's funding model.

3.2 The wider context

Outside the academic environment, the primary beneficiaries are the target communities themselves, of course. The Bottle Buoy and two other devices - along with targeted community education - aim to have a significant effect on global drowning rates, with Bangladesh's shocking 18,000 child drownings per year as the initial focus. Such events have a devastating emotional and economic impact on the local and regional communities, and it is rare that a single product can hope to have such a wide-reaching and fundamental effect. The equipment items developed will now be contextually tested by the Centre for Injury Prevention and Research (CIPRB) in Bangladesh to ensure that communities will accept and use them for their desired function.

LRC projects have also been found to propagate unexpected additional benefits to local communities. One example resulted in the creation of possibly the first Bangladeshi custom surfboard design and manufacture business as a spin-off from the building of rescue equipment.

For the RNLI, alongside the increase in capacity for design projects which will ultimately allow them to achieve their stated objectives, working with students fulfils an important goal in engaging with local education practice and academia. RNLI engineer Rob Debbage acknowledges the importance of helping to nurture local talent in this way:

"The RNLI's direct engagement with students at a critical point in their development enables us to harness young talent and creativity, whilst raising awareness of our purpose and delivering key messages. Through student engagement, we hope to cultivate the future innovators in lifesaving."

It has also been found that Product Design students offer a perspective on design problems that is different from in-house design engineers. Career engineers used to working on boat-related issues tend to be restricted by constraints imposed on them by their subject-specific knowledge, whereas the breadth of projects that BU students tackle enable them to perhaps look at challenges in a more abstract and holistic way. Students also tend to offer a more human-centred design solution than technically-minded engineers.

From a more environmental perspective, the benefits of developing sustainable design solutions – from an ethical, social and economic point of view – have long been expounded by a huge number of researchers, of course, and many of these stress the importance of achieving sustainability through greater consideration for the local context (Elkington, 1994; Zurlo & Nunes, 2016). Vadoudi, Allais, Reyes and Troussier (2014), amongst others, encourage designers to shorten the supply chain by utilising "local resources for local use". Morelli (2013) also calls for designers to involve local institutions, service providers and individuals, and "to adopt a new paradigm of design to operate production and consumption processes".

4 THE CHALLENGES

4.1 Designing for unfamiliar communities

Aranda-Jan, Jagtap and Moultrie (2016) produced a "holistic contextual framework for guiding the design decision-making process" in a LRC context. Although this framework was specifically produced for medical products, it offers a useful breakdown of the factors that need to be recognised and assessed by designers working on any LRC projects. Alongside the issue of public health – which may be considered less of a priority for non-medical devices – it specifies seven distinct categories of factors:

- Socio-cultural (e.g. literacy, language, religious beliefs)
- Infrastructure (egg access to electricity and water, transportation links)
- Geographical/environmental (e.g. temperature, community remoteness)
- Institutional (egg availability of funding, government involvement)
- Economic (e.g. GDP, poverty level)
- Industrial (egg manufacturing methods, supply/distribution chain)

While some of this information – such as geographical factors and GDP – can be readily accessed online, many of these areas are at best difficult for students to analyse without heavy involvement from someone with first-hand knowledge of the target community. One former BU student specifically stated that "sourcing reliable information on local production techniques was particularly difficult". This lack of information can range from the likelihood of the availability of semi-industrial manufacturing methods to simple things such as whether the target community has access to tape measures and glue. He also found himself heavily reliant on RNLI links: "I feel that without the links to my target users I had via the RNLI, I would have been at a significant disadvantage". In particular, it may be extremely hard for a Western student to gain a comprehensive grasp of the full range of socio-cultural factors at play in remote LRCs. As one student put it: "I think the University expects a lot from students working on these types of brief, in terms of obtaining first-hand information from hard-to-reach markets/users".

4.2 Academic supervision

Low-resource projects can often involve communities and issues outside the usual parameters of educators' knowledge and experience. If tutors are unable to provide specialist knowledge on the specific issues – and potential range of solutions – for a project, this may well present a major cause for concern. In Bournemouth University's case, the Product Design final year has been developed around the ethos of problem-based learning (PBL). For many years debate has raged as to whether

PBL is best supported by tutors who have a detailed knowledge of the problem area – so-called content experts – and those who have relatively little knowledge – so-called content novices (Gilkison, 2003). A meta-analysis of previous research conducted by Leary, Walker, Shelton and Ertmer (2013) concluded that “content expertise is not a significant factor” in the success or failure of effective problem-based learning, a result which echoed the previous results of analysis by Park and Ertmer (2007). It may seem therefore that educators should not be concerned about a lack of specialist knowledge of low resource communities.

However, some evidence drawn from student experience suggests that students do value tutors’ knowledge of the associated content, and lack of knowledge could therefore have a negative effect on students’ morale and level of respect, even if the outcome is successful (Feletti, Doyle, Petrovic & Sanson-Fisher, 1982). Interestingly, the authors’ own research with former students suggests that they may feel disadvantaged, or alternatively feel more empowered: “I was dealing with a market which perhaps few of my lecturers had first-hand experience in, and so [they] became more reliant on my first-hand information”. Either way, it is conceivable that an inability to provide specialist help could be damaging to a tutor’s own morale and confidence. BU is in a fortunate position, having access to academic staff with professional experience in LRCs, and it is debatable whether such projects would be so readily embraced without this.

4.3 Assessment

LRC student projects present academic issues alongside the practical difficulties. At BU design validation is a major factor in the assessment of final-year Product Design projects, and without relying on the opinions of outside experts it can be hard to ascertain whether the product offers a practical and appropriate solution to the defined challenge. It must be recognised that LRC projects are not alone in this; medical devices, for example, can present a similar challenge. For these kinds of projects BU therefore insists that students obtain professional validation for their final design.

There is an added complication when prototypes require assessment. At Bournemouth University, Product Design students’ prototyping skills are assessed separately from the rest of the project, comprising an individual unit worth 20 credits. LRC products can on occasion be highly complex and involve substantial prototyping ability, but this tends to be the exception. More often the product is intentionally designed to be simple and easy to manufacture with comparatively low levels of skill. This can present major issues of parity with other students, most of whom are required to replicate precise, working products designed for Western manufacturing processes using their own manual prototyping skills. BU attempts to address this discrepancy in part by insisting on students using – as much as is practically possible – exactly the same materials and techniques as would be employed by the target producers; for example, using manual tools instead of machines. In addition, students with simple products are more heavily penalised for any inaccuracies in their prototypes. However, in the event of a student having no inaccuracies when a product consists of little more than a length of rope and some rough-cut wood, it can be hard to defend a prototyping mark of less than 100% - a result which would be practically unachievable by students with non-LRC prototypes.

In order to further redress the balance and present additional academic challenge in these projects, BU also requires that some kind of accompanying document forms part of the product solution, and this is presented alongside the prototype. Usually consisting of a construction guide or information booklet, it is heavily scrutinised for its suitability for the given socio-cultural conditions, its use of semiotics and colour psychology, and the standard of presentation, amongst other things. In practice, this document can sometimes have a greater impact on the final grade than the accompanying artefact, and this may provide a bone of contention. It must be acknowledged that – although this has increased the level of challenge for the student – it is not offering a fully valid test of prototyping skill as such, but instead assessing the student's abilities with copy, layout, graphics and software such as Adobe InDesign and Illustrator.

4.4 Compliance

Modern effective lifesaving equipment is often designed to comply with relevant design and engineering standards. Although in a developed world context this would ensure that the product is fit for purpose, in a low resource environment, the RNLI's sustainable equipment project has discovered that compliance can make lifesaving products prohibitively expensive and therefore not accessible to the very communities that desperately need them. There is obviously a careful balance between the benefit of having non-compliant equipment and the risk that non-compliance poses. The RNLI's Engineering and Asset Management value stream newly developed FMECA (Failure Mode, Effects and Criticality Analysis) tool, named 'SHARK-DAT' is being used to mitigate this risk during design. This process, (originally designed for lifeboat design and manufacture) provides assurance and design verification of lifesaving equipment that falls outside of standards and regulations.

5 MORAL & SOCIAL ISSUES

The RNLI's International team are developing operational and educational interventions to prevent drowning in a number of low-resource regions. In Bangladesh it was found that there is a need for lifesaving equipment to support both education and rescue operations. The purchase of western designed and manufactured equipment is often not financial viable, sometimes because of unfair trading practices. Some life-saving equipment manufactured in South Asian countries by European companies is bizarrely shipped several thousand miles around the world before being resold to those same countries at a massively inflated price. Because of the high cost of this equipment it was discovered that native versions were being created from locally available materials. However the function and reliability of these devices were often compromised due to an apparent lack of understanding of the key functional requirements. The RNLI therefore initiated a project with the aim of providing appropriate instructions to local communities for the low-volume production of equipment based on the locally available materials and manufacturing methods, but it was found that the product design skills and knowledge essential to create the best possible solution were not available in the local context. One of the authors - as programme manager of the project and also a lecturer in product design - saw the potential benefit of utilising UK undergraduate product designers to help with design solutions.

The question must be asked as to why countries like Bangladesh have become reliant on students on the other side of the world to design product solutions to local problems. Literature around design in Bangladesh is limited but does corroborate the anecdotal evidence found by the RNLI's programmes team. Banu (2009) cites a Design Without Borders report produced in 2003 that indicates a 'design deficit' and situates design in Bangladesh within the context of social development (Knutslien & Thommessen, 2003). He presents four factors that are missing from design in Bangladesh:

- Policy – No national or corporate-level design policy exists, and there is no national accreditation system.
- Profession – There is a shortage of local practitioners.
- Education – Alongside the shortage of design educators, the lack of any Masters-level course means that design research is virtually non-existent. Crucially, although Bangladesh's capital city Dhaka does have two universities that offer courses in Product Design, the focus is on training students to produce western-influenced designs intended for export rather than indigenous products that satisfy a local need.
- Definition – Bangladesh has no design identity and no engagement with modern design development. This breeds a lack of familiarity with design concepts and language, and consequentially design is regarded as a product rather than a process.

Public rescue equipment is not commonplace in Bangladesh communities and further research is required to find out if it will be readily accepted and used. In some instances communities are simply resistant to the relatively novel concept of making or purchasing equipment for public access for occasional use in the event of an emergency. In other cases, low resource products have been rejected because of superficial perceptions. Some early indications from research in the use of playpens to reduce the risk of 1-5 year-olds straying from home and drowning in nearby ponds has suggested that communities favoured the more expensive plastic versions to the cheaper wooden versions due to perceived social status – despite the fact that both products performed the same function equally well. In another example, one major rescue organization declined to use the low-resource version of a rescue product in favour of a similar product used by the RNLI. Again, both items perform the same function, yet the RNLI version costs almost ten times as much.

6 THE DESIGN PROCESS

As part of the RNLI's International Drowning Reduction Strategy, several items of low resource equipment have been designed due to need from communities. These items have been designed using the traditional engineering design flow, similar to that proposed by Ertas and Jones (1996). However, this process was created for linear design and does not allow for physical and cultural separation between the user and designer. It is also based on the final design being a physical product rather than an instruction manual that instructs a community member how to make that product in a sustainable way.

The knowledge and experience gained from previous LRC projects has enabled the authors to formulate a new design flow for low resource product development (Figure 3). This process integrates the traditional design flow with both agile and human-centred design (HCD) methodologies. This new design flow will be trialled over the next project period and will be updated and adapted as necessary.

There are also lessons to be learned from the small but growing band of designers, engineers and innovators springing up in some parts of South Asia. One example is Uddhab Bharali who is celebrated in India for his low-cost agricultural inventions and is now turning his skills to aids for the disabled (Rice, 2017). Bharali has produced over 140 inventions – some garnering international awards – using the philosophy of jugaad innovation. Jugaad, a Hindi term translated as "ingenious improvisation", represents a bottom–up approach to frugal and flexible innovation, and is increasingly becoming incorporated into design planning. LRC projects particularly stand to benefit from its six core principles:

- Seeking opportunity in adversity.
- Doing more with less.
- Thinking and acting flexibly.
- Including the margin.
- Following your heart.
- Finally - and crucially - keeping it simple (Radjou, Prabhu & Ahuja, 2012).

Developments in design thinking are increasingly having significance outside the design and engineering sphere. The RNLI is one of several organisations now using design thinking in organisation-wide development activities (Brown, 2009). The RNLI innovation and corporate planning departments have begun embedding these practices into strategic, tactical and operational planning.

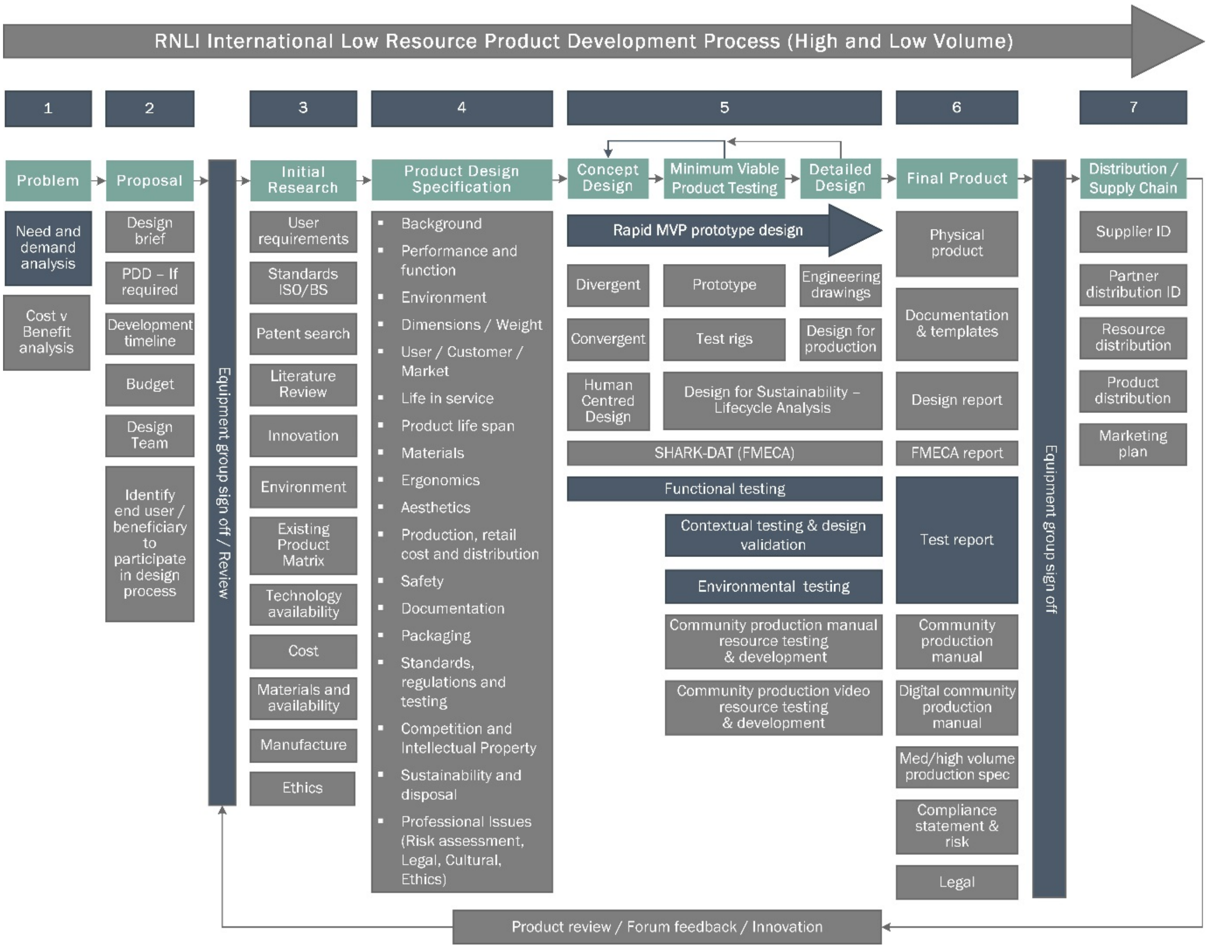

Figure 3

7 LOOKING TO THE FUTURE

7.1 A community of practice

The authors' research exposed the problems students face in trying to accrue comprehensive reliable information about LRC's. It would seem sensible that greater co-operation and knowledge sharing – between NGO's and academic institutions in particular – would make great strides in alleviating this problem. One student voiced the opinion that "it would be extremely valuable to students working on these briefs if the University and lecturers continued to build links with organisations working across the world. These links could be used to the students' advantage, as a means of helping them obtain first-hand information".

The RNLI are currently making moves in this direction, with a proposal to create Rescued by Design. This would be a central resource hub, a one-stop shop for accessing information and designs related to lifesaving equipment. This proposal builds on the concept of a 'community of practice', as proposed by Lave & Wenger (1991). The key characteristics of a community of practice are threefold: that it represents a joint enterprise with a common theme between members; that mutual interaction between members generates a social identity; and that a repository of pooled knowledge and resources is built up over time (Wenger, 1998).

Such communities of practice are currently in widespread use in areas such as education, agriculture and anthropology, and the authors believe that there is both scope and appetite to adapt the model to thematic areas within product design. Prior to BU's involvement, the original Bottle Buoy concept was originally created by a student at University of Huddersfield, James Benson, and it is only due to its chance discovery by the RNLI that BU was able to subsequently help in its development into the product currently being trialled. While there are undoubtedly issues to be resolved concerning IP and plagiarism, greater access to information amassed as part of prior design projects could help both students and NGO's develop truly appropriate solutions.

As well as offering a practical framework for discussion and the sharing of information around a common theme, communities of practice also provide an alternative method of education, termed 'situated learning'. As opposed to the internalised, academic view of education, 'learning as increased participation in communities of practice concerns the whole person acting in the world…[with] an evolving, continuously renewed set of relations' (Lave & Wenger, 1991). This could have added benefits in an area such as Bangladesh where shortfalls in design education and safety awareness could be addressed directly.

7.2 The global society

During a recent visit to Nigeria and Kenya, Facebook CEO Mark Zuckerberg visited a number of establishments helping to encourage local innovators and designers to develop their ideas, including Co-Creation Hub Nigeria and Kenya's Gearbox maker-space (Dubey, 2017). Gearbox offers access to training and facilities for designing and building prototypes, and fosters a community of technical experts, creatives, entrepreneurs and makers. Its creator, University of Nairobi lecturer Dr Kamau Gachigi, stressed during the 2017 TEDGlobal conference in Tanzania how important such spaces – and such communities – are, for helping local people to create solutions suited to their specific environment and circumstances, and for encouraging local practical skills and productivity: "We need many more people to develop their potential and contribute to society." (Wakefield, 2017)

MIT professor Clapperton Mavhunga also champions the establishment of local creative spaces in low resource societies, based on the innate traditions of cooperation and community as opposed to the Western predisposition for individual innovation (Mavhunga, 2014). Moreover, he proposes that the key to successful solutions is to encourage the fusion of formally educated, skilled expertise with homegrown wisdom and creativity. Whilst his message is mainly focused at inspiring African students to re-establish their links with their native communities, the core sentiment that "we should spread our net wide to embrace all of society in innovation" is supportive to greater wholesale collaboration across borders and backgrounds.

The rapid global spread of modern technology has made a massive difference in our ability to carry out low-resource projects. Email in particular has been a huge benefit in BU projects, allowing students and the RNLI to connect with remote and distant communities in a way that would have been impossible a decade ago. It may seem surprising, but Bangladesh possesses more mobile phones – over 130 million - than most European countries (BTRC, 2016). Although smart phone ownership is relatively low at 8.2 million, this figure is set to expand massively over the next few years, and over 60 million members of the population are connected to the internet via their phones (Hussain, 2016).

The spread of the internet and mobile technology to formerly remote communities offers an immense opportunity for design students, academics and low resource communities to engage with global and local issues in a newly productive and meaningful way. Mark Zuckerberg recently offered his own view on the solutions that could be created:

"Our world is more connected than ever, and we face global problems that span national boundaries. Our greatest challenges also need global responses -- like ending terrorism, fighting climate change, and preventing pandemics. Progress now requires humanity coming together not just as cities or nations, but also as a global community." (Zuckerberg, 2017)

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Decision Making in Product Design: Bridging the gap between inception and reality

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Abstract

Product Design in the modern world is a complex multifaceted discipline comprising of many skills and applications. It also operates in broader cross-disciplinary contexts within direct teams, while also contributing to the strategic business processes of commercial enterprises, government/councils and not for profit organizations. It is no longer a purely creative problem solving activity where a good idea or innovation is enough to push forward a new product. For the majority of the design profession the days of design on the back of an envelope are gone. Today design is a structured activity with recognizable and repeatable methodologies and processes. Within this the profession is acknowledging and aligning with the principles of business management. A consequence of this is that designers are being asked to undertake increasingly complex challenges where the consequences of making good or bad decisions have far reaching implications for the future of an organization. Education needs to train designers to recognize and operate in these complex situations. As a response Universities now include project or design management within curriculum.

'The new program 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' (Guo, 2015)

However the authors have recognized a gap within the profession and education for a more structured and validated approach to decision making within the design process (Norman, 2010). This paper outlines a pilot study within a student project whereby professional decision making tools are introduced to final year students and used to validate selection of appropriate designs from initial feasibility concepts against a hierarchy of criteria. Would designers see the value or would they perceive it as an intrusive addition to what they believe should be an intuitive process?

Key words

project management, decision making, selection tools.

1 Introduction

Product Design has grown rapidly in the last few years from a creative response, solving problems in imaginative ways, to a more complex professional activity. With the former, product designers justified their work through presenting ideas as images and models, the value of which being defined by how "wow'd" the client was at the presentation. Although this is a simplistic view it reflects the starting point of the profession which is gradually becoming more sophisticated in how ideas need to be justified against contexts, and validated using repeatable design processes and methodology. Two key pieces of work are the book Design Management by Kathryn Best (2006), which crystallized our understanding of the value of design to industry and the UK's Design Council Double Diamond description of the Design Process (Design Council, 2015). The Double Diamond is a way of visualizing the design process as four discrete stages Discover-Define-Develop-Deliver. The latter two stages develop and deliver are well understood, where a designer's creative response to a given product specification, or narrow brief supplied by another is made real through concept generation, review, refinement and prototyping, combined with an understanding of production processes. This Develop and Deliver window from brief to product reality is the bedrock of what is taught in universities and colleges. It forms the essential proving ground for building skills and creative sensibilities. With the increasing acceptance of the idea that Design Thinking is a legitimate business tool (Rauth, Carlgren & Elmquist, 2014) to drive innovation designers have developed beyond this reactive role to working at the very inception point of product creation, to identifying what could be, as much as how to make it a reality. There are now numerous tools and methods (Kumar, 2012) available to the designer to formalize research into new possibilities driven from the perspective of the end user. These can range anywhere from ethnographic observation techniques to direct immersion of the designer in the user environment. The Discover phase of the Double Diamond process is specifically aimed at focusing designers on conducting this first hand research to quiz needs prior to formulating Design Specifications. This is a key step change in that it allows designers to interrogate real rather than perceived needs, ensuring that they are answering the correct question in the brief. Much work has been done in this area, indeed Design Research is now a professional discipline in its own capacity (Milton & Rodgers, 2013; Laurel, 2003; Muratovski, 2016). However, the define phase is still a grey area. That is, how do we move from a new level of user needs understanding, including design propositions, within the Discover phase to a Product Specification and viable business proposition? What criteria do we use to make choices? This is a poignant question within the Develop and Deliver phases as well, how exactly do we make decisions? We may be answering the right questions but with the wrong answers, or we may be providing great answers, but to questions that don't need asking.

This paper is the start of a collaborative research project between Industry and Academia investigating current understanding of the above issues and tentative field-work with a student project to identify criteria, and the priority that should be placed on those criteria, by which choices can be made using a tool created with the industrial partner (HCL Technologies Ltd).

2 the design process

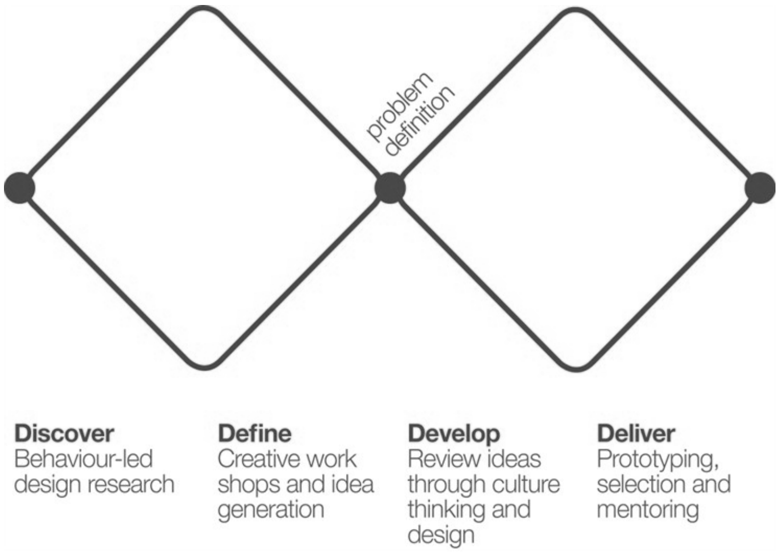


Figure 1. The Design Council Double Diamond Design Process (Design Council, 2015)

The articulation of what constitutes a Design Process is not new (Jones, 1992; Lawson, 1995; Guo, 2015), and has evolved into a sophisticated process both in terms of a channel for creativity and a commercial construct. However there is still a tendency to regard design as an unpredictable creative process which generates invention, right brain or outside the box thinking, misunderstood in the external world. Whereas creativity, identifying new needs and responding with possibilities is indeed part of design there is a difference between Invention, Innovation and Design (Best, 2006; Lawson, 1995). Although none of these are the exclusive domain of product designers a professional designer does understand and follow processes to get from invention (or other starting point) to realization. The latter two, innovation and design, are a disciplined process by which products (products, rather than service or system, used as an example in the context of this paper) are realized in response to needs or requirements. Product or Industrial Design as taught in a modern University is a complex vehicle which both reflects commercial practice and challenges existing paradigms. An integral part of this is the teaching of design process or method. At the University of Hertfordshire after a broad discussion on the processes available the students follow the Design Councils Double Diamond Process (DDP), see Figure 1, as it is both visual and clearly articulated. It is also important as it links the traditional commercial understanding or utilization of design as a development and delivery process with the need to discover or research user needs. This is crucial to good design as design research is where real needs or possibilities are both uncovered and understood. As Sir Ken Robinson expressed it:

“You cannot solve a wrong problem” (Robinson, 2013)

Tools used in the Discover phase and idea generation aspects of the define phase have been adopted by design professionals to help articulate the benefits of Design Thinking and creative approaches, and much work has been done here, indeed Design Research is a profession in its own right. This plays strongly into the ability of designers to expand possibilities and identify a plethora of opportunities. What is less understood is how students and designers navigate from the many opportunities identified in the early phases to a validated development pathway. What is the decision making process? Is it arbitrary or does it follow a clear set of value judgments? This conundrum is echoed on the critical decision pathway from the define phase to the develop phase. The authors believe that there is a need for more user focused and design led processes to fill the design decision gap, see Figure 2, between Define and Develop phases. There is a need to provide designers with tools (Diels & Ghassan, 2015) that give them confidence to become a crucial part of the decision team, and be less inclined to abdicate decision making to financial, marketing and engineering gate keepers.

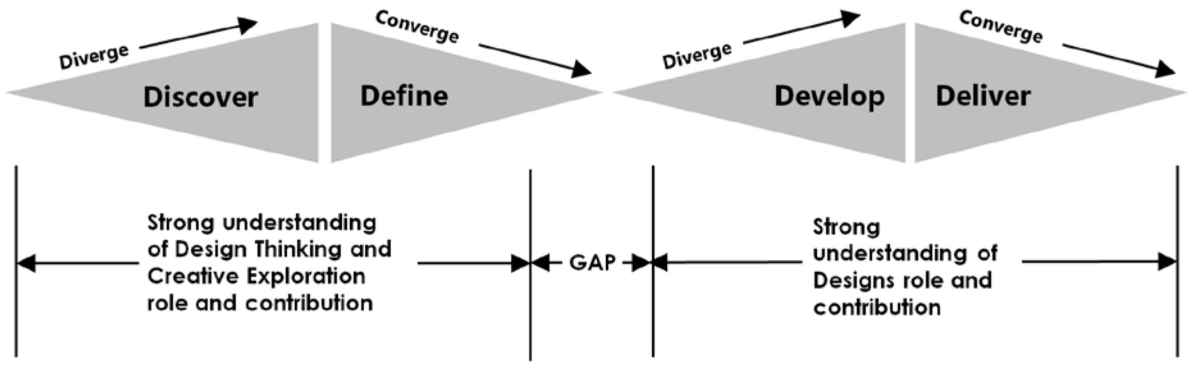


Figure 2. Design Decision Gap in the DDP

If some of the commonly used tools and techniques are mapped against the DDP, see Figure 3, it can be seen that the closer to a critical decision point in a project the more quantitative tools and techniques come to the fore. Designers by their very nature tend towards the more qualitative tools and techniques, which often results in their voice not being heard at the crucial decision points in the product creation process. While there is undoubtedly a shift to acceptance of the value of the qualitative input at a theoretical and ideological level the decision makers in organizations still tend to be from a more commercial focused background and are under relentless pressure to deliver results at minimal risk. They desire an algorithmic approach to innovation where a specific input to the process repeatedly guarantees a successful outcome. Basing decisions on metrics, even if those metrics are disconnected from the reality of user needs and customer desires, provides the illusion of certainty and something to blame if things go wrong. The need for organizations to break out of this approach is crucial if they want to take advantage of Design Thinking. As Roger Martin states:

“Knowledge Management systems will organize all the knowledge in a corporation, but they cannot produce imaginative breakthroughs. Advances in knowledge emerge from the pursuit of valid results. That pursuit calls for a different set of tools and processes…” (Martin, 2009)

The use of analytical tools that quantify subjective input may provide an opportunity for designers to engage with the decision process more fully. If designers cannot articulate, validate and present reasons for their recommendations it is likely to remain the case that designers will continue to be in the position of creator-artisan looking to the judgement and approval of patrons in the form of clients or senior management decision makers. It is rare for a designer to present one idea to a patron accompanied by a well thought out validation and rationale; rather, it is more likely that the designer will present three or four ideas for the patron to pass judgment upon. In this way the responsibility for outcomes passes to the patron. As designers engage earlier in the new product development process, with much of their work being in the pre-definition phase, they will need to take responsibility for the increased impact their input has on success or failure. They need to be judge as well as creator.

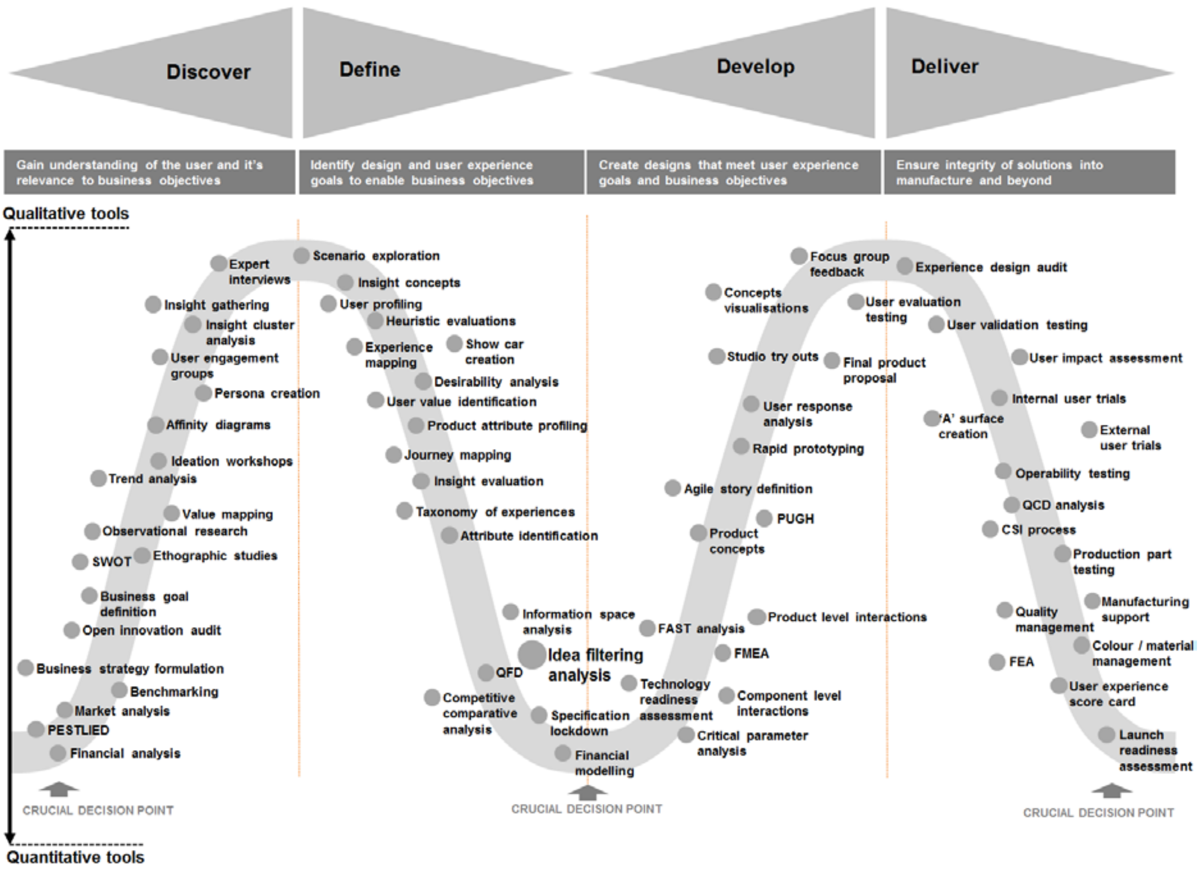


Figure 3. HCL Ltd. Tools and Techniques mapping.

For designers to take on this role the design education system will need to provide an analytical framework for design students to build upon, while continuing to provide the opportunity for the development of skills and creative flair. The aim being to provide students with the tools and techniques that will allow them to have confidence in their decision making and instill in them an understanding of the importance of robust design research in gathering valid data Within the project outlined below students were introduced to some of the tools currently available to aid decision making.

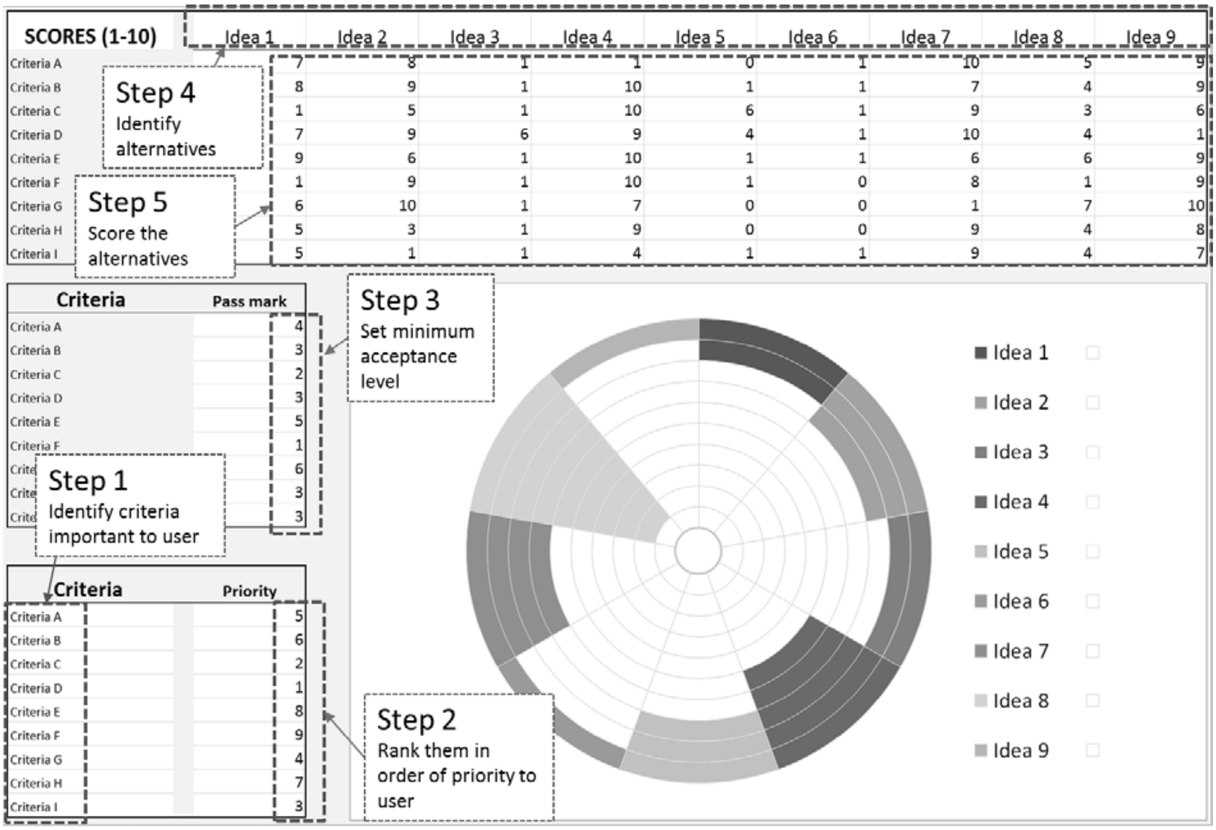
3 The student project

To explore with students the available tools to validate decision making in design a reflective task was incorporated into a design project. This 'new to students' aspect of design involved a realization of the complexity of the process as well as creativity within design. In collaboration with HCL Technologies Ltd (HCL) a challenge was set to final year Industrial and Product Design students to individually:

'Design and test a product to help the disadvantaged utilizing the technology of 3D printing'

The project was structured around the DDP. The first phase was to identify needs through research and present these 'design insights' (Taura & Nagai, 2008), back to the company, considered as the Discover Phase. Through further observation and refinement students then responded creatively generating design possibilities, in response to identified needs, as sketch sheets. This in effect reflected the first aspect of the define stage. Another session took place with students presenting these concepts. This was followed by a seminar facilitated by HCL and University of Hertfordshire, on how to make appropriate selection from the generated possibilities. In this session a selected number of assessment tools and matrices were introduced to the students. These included QFD (Quality Function Deployment), Pugh Analysis (Pugh, 1990) and Desirability Competitive Positioning Model (Wynn, 2014). It was hoped that by giving the students a clear understanding of the importance of decision criteria early on that it would give them an insight into how professions outside design use models for decision making.

The aim was to expose the students to rigorous selection tools and processes that would help them dispassionately assess and define what design directions should progress to development. The outcome of the exercise was to gain an understanding as to whether having a defined process for concept assessment would impart more confidence in the students to defending their decision rationale. Of the tools introduced to the students the tool chosen for the exercise was one created within HCL called the Idea Filtering Analysis model. It was chosen due to its position in the development process, see figure 3, and its combining of an analytical approach with subjective input. The model uses criteria as identified during the Discover phase (step 1), and through a combination of heuristic evaluation and user engagement stack ranks them in order of relevance to user needs (step 2). Each criteria is then given a minimum pass mark (step 3), i.e. the minimum level that users would deem the criteria met sufficiently to avoid a given idea or concept being rejected by the user. This is the level that meets user expectations, exceeding this does not gain anything over the competition unless it is as a tie breaker when only two contenders remain. Each idea generated during the early define phase (step 4) is then scored against the criteria (Step 5). In this way the ideas pass through a series of criteria filters that identifies the idea that is likely to provide the best chance of meeting the user needs. The outcome is displayed as a visual chart where the idea that gets closest to the center is the winner. While numeric outcomes are sufficient to identify the winner, visualizing the results was considered important to allow designers to relate to the outcome. Figure 4 shows example data displayed in the Idea Filtering Analysis model, and illustrates how ideas can be exceptional against many of the criteria, exceeding user expectations, yet fail if the crucial early criteria filters are not passed. Idea 9 can be seen to be out performing idea 8 in all areas except the crucial highest priority criteria (criteria D). Meaning an otherwise very strong idea such as idea 9 fails and a better focused idea such as idea 8 succeeds.



SCORES (1-10)	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7	Idea 8	Idea 9
Criteria A	7	8	1	1	0	1	10	5	9
Criteria B	8	9	1	10	1	1	7	4	9
Criteria C	1	5	1	10	6	1	9	3	6
Criteria D	7	9	6	9	4	1	10	4	1
Criteria E	9	6	1	10	1	1	6	6	9
Criteria F	1	9	1	10	1	0	8	1	9
Criteria G	6	10	1	7	0	0	1	7	10
Criteria H	5	3	1	9	0	0	9	4	8
Criteria I	5	1	1	4	1	1	9	4	7

Criteria	Pass mark
Criteria A	4
Criteria B	3
Criteria C	2
Criteria D	3
Criteria E	5
Criteria F	1
Crite	6
Crite	3
Crite	3

Criteria	Priority
Criteria A	5
Criteria B	6
Criteria C	2
Criteria D	1
Criteria E	8
Criteria F	9
Criteria G	4
Criteria H	7
Criteria I	3

Figure 4 Idea Filtering Analysis.

Figure 5 shows the significant impact that changing the priority of criteria D can have and illustrates the complex and delicate interrelationship between criteria, user priorities and to what level does an idea address those criteria. The change in priority of criteria D means that idea 9 is able to take advantage of its strength in addressing other criteria to win out over weaker ideas. This tool allowed the students to run alternative interpretations of data and provided a real example to the students of how lack of understanding of the user in minor ways can have a disproportionate impact on success. In demonstrating this sensitivity it was hoped that the students would also see the importance of good quality design research that provides data they can critically evaluate and have confidence in utilizing within a design process.

SCORES (1-10)	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7	Idea 8	Idea 9
Criteria A	7	8	1	1	0	1	10	5	9
Criteria B	8	9	1	10	1	1	7	4	9
Criteria C	1	5	1	10	6	1	9	3	6
Criteria D	7	9	6	9	4	1	10	4	1
Criteria E	9	6	1	10	1	1	6	6	9
Criteria F	1	9	1	10	1	0	8	1	9
Criteria G	6	10	1	7	0	0	1	7	10
Criteria H	5	3	1	9	0	0	9	4	8
Criteria I	5	1	1	4	1	1	9	4	7

Criteria	Pass mark
Criteria A	4
Criteria B	3
Criteria C	2
Criteria D	3
Criteria E	5
Criteria F	1
Criteria G	6
Criteria H	3
Criteria I	3

Criteria	Priority
Criteria A	5
Criteria B	6
Criteria C	2
Criteria D	9
Criteria E	8
Criteria F	1
Criteria G	4
Criteria H	7
Criteria I	3

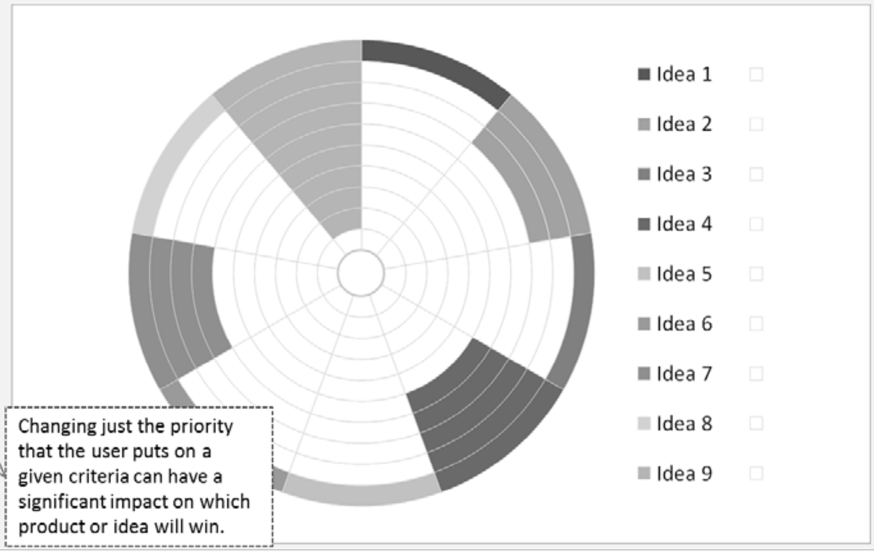


Figure 5 Idea Filtering Analysis – impact of minor change in priorities.

The students were required to present the outcomes of their idea filtering analysis to a surrogate client, represented by a business manager from HCL, as a set of recommendations in the form of product attributes aligned to the prioritized criteria. The emphasis was on requiring the students to make decisions rather than the more traditional format of the designer presenting work and the client choosing a development direction. Having used the tool to support their recommendations the students were asked to provide feedback on whether they found it useful in articulating their rationale and decision as to which of their concept ideas deserved to progress to development.

The continuation of the project allowed students to refine concepts into practical design proposals, within the manufacturing limitations and possibilities of 3D Printing. This was in line with the develop phase of the DDP. Students were charged with continuing to use the tool/matrices in their decision making pathway as ongoing validation of their design selection. At the next formal meeting final proposals in the form of 2D Presentation were presented along with the completed tools/matrices. Did they feel more confident in making and defending their decisions by having formalized analysis tools?

4 Student feedback

The project was undertaken by 12 students. At the end of the project each student was given a short questionnaire (9 responses). The authors accept that due to the low number of participants the results are indicative rather than conclusive. However the following observations from the students are invaluable for the construction or refinement of assessment tools within an educational context. The questionnaire included the following questions:

- *Did you find the Tools useful?*

60% stated that they did not find the tools useful. However when analyzing comments made to other questions (see below) this is in part an indication of not wanting to externalize decision making and a preference to do what the student wanted rather than deliver against criteria.

- *Did you develop the Design Concept indicated as the best aggregate score on the Pugh Diagram?*

60% of the students responded yes which appears to be in conflict with the answer to the question above. Of those who answered no, comments such as *"I trusted my instinct"* and *"I developed the one I wanted anyway"* were given. This indicates a lack of engagement with the complex business world in which design operates. That is although the tools may not be the full answer professional designers do need to respond to external demands and criteria rather than just do what they want. It is also important to frame decision making in a business facing language.

- *Did you find the tools useful in thinking about the criteria for the design even if you did not adhere to the findings?*

This is probably the most insightful feedback. That is although there are issues with engagement with current tools they did expand the understanding of process and decision making. Two key comments were *"Yes new perspective but ignored the ratings"* and *"more insightful than useful"*

- *List three good things about the tools.*

Although there was mixed opinions about the value of the tools (answers to questions above) there was a general feeling that they could assist in making rational choices, particularly when there are multiple design options or opportunities and that they "*allow designers to justify their decisions*"

- *List three areas in which the tools could be improved.*

Interestingly only 40% of students answered this question. However, those who did felt the diagrams could be simpler both in the application of data and visually.

5 Further research and development

This is early stage research mapping out a territory for investigation. Building upon existing frameworks and protocols (Best, 2006; British Standards Institution, 2008), the value of the preliminary project can be summed up in the following points:

- To understand the modern design profession design students should contextualise their creativity and skills against robust methodologies and practices.
- Decision making, milestones and a critical pathway are crucial to successful projects.
- Tools and Matrices are valuable aids to both decision making and communicating these to external associates (clients).
- Evaluation tools are relevant at different points on the critical pathway within a design process, and these tools need to be explored further.
- There is some resistance to analytical approaches from designers themselves and ways need to be found to communicate the value to these approaches in a way that is not seen as intruding on the creative and intuitive strengths of designers.

There are numerous tools that can be used to compile and analyze subjective data and present this data in a way that can be interpreted by non-designers, however, until designers themselves see the value that these tools can provide there is likely to be resistance to their adoption.

One key observation by both HCL and University of Hertfordshire staff was that selection tools such as the ones outlined in this paper cannot be introduced to students without prior work on the professional processes involved within the business of the Creative Industries. That is, the value of selection tools is greatest when design decisions are externalized against commercial criteria rather than internalized with the designer, or in the instance, the student making all the decisions against their own preferences. This is also a key differential between the professional product designer and the designer maker or artisan designer who is controlling the whole of the design process from conception to manufacture. The selection tools bring a business context and language to the design process that can help designers validate and rationalize their thoughts in a way that is understood by other participants in the decision process. However, the authors believe that if selection tools of the type explored during the student project are to be taught effectively they need to be introduced to students only after an understanding of the broader business processes of design are gained. Within the three year Product & Industrial Design curriculum at the University of Hertfordshire the creative and business processes are taught as follows; the creative process is taught in the first year while business aspects are introduced in the second year (simplified outline). Thus selection tools, taught in the final year, are building on this learning curve only when the students have a mature understanding of Product Design and are generating personal portfolios demonstrating their capacity to enter and practice within the professional discipline.

Building on these early observations more structured research is needed to explore the utilization of tools within a broader range of design processes. Even within the DDP tools can be used at the end of the define stage and also the development stage, will they be the same tools? This needs further investigation. Student projects will be used to explore development of tools appropriate to design strategies. In the project described above professional tools were introduced to the students. On a positive note this also made students aware of the complex nature of decision making in a business context. Commercial decisions normally have inputs from a range of disciplines covering all affected parties such as finance, marketing and production as well as user/customer concerns. However some students struggled with the complexity of professional criteria and there is the potential for the development of entry level tools which match the students understanding of commercial design in a similar way to understanding manufacturing processes. That is a professional designer through experience has a better grasp of rationalizing production processes than students who have limited experience in these technologies. One aspect of this is the visual nature (info graphics) of the tools and grids and there is an opportunity to simplify the presentation here. Whereas they should be robust and validated they also need to be accessible so that information can be understood by a range of professionals beyond design. Our aim is:

Creation of a broader balanced scorecard approach and guidelines that ensures the more qualitative aspects of project appraisal is given an equal weighting with the more conventional quantitative approaches, and seeks to identify opportunities for successful innovation that would otherwise have been overlooked. In particular to provide an approach that is tailored for use by designers and is perceived by them as a real value in building credibility and helping them articulate real value.

While introducing the concepts to students is considered particularly useful there is also a potential gap within the practicing design profession with regard to becoming more prominent in decision making and it is believed that by building student confidence by providing them with the right tools they will be better prepared when entering the profession.

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23.2

MOBILE EYE TRACKING IN ENGINEERING DESIGN EDUCATION

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Abstract

A central part of basic engineering design education aims for imparting profound knowledge of how machine elements are designed and building an understanding about how they work in detail within a technical product. In this context, a basic challenge lies in teaching to analyse complex systems that are usually characterized by a high number of interacting parts and interfering movements. In our basic engineering design education at ETH Zurich, we recognized that high-performing students in functional analysis are able to gain more insights from analysing machine systems than low-performing students. Indeed, high-performers are not only effectively using previous knowledge, they are also more successful in identifying relevant parts. This observation raises two questions. (Q1) Which previous knowledge is required to single-handedly be able to fully understand how a specific system works? and (Q2) How can we support students in drawing special attention to the relevant parts and the areas revealing their role within the system? In order to answer these questions, we conduct a mobile eye tracking study, including concurrent reporting. Students are asked to analyse a small, but difficult to understand machine system and to explain how it works. This paper highlights the differences between successful und and non-successful functional analysis and discusses them in the context of the two questions presented above. The two main results of this paper are that successful students had a wider knowledge-base of mechanical systems and that analysis strategies like "following the flow line of force" gives a guide rail. Both helped them to identify single sub-functions and to evaluate their importance.

Key words

mobile eye tracking, basic engineering design education, functional analysis, comprehension process, foreknowledge, high- & low-performers

1 Introduction

One of the main challenges in basic engineering design education is to impart the ability to functionally analyse technical systems. The most promising approach in our lecture courses is not only to present simple standard components taken out of context. We show and analyse in detail realisations in more complex everyday products with combinations and modifications of standard components. The intention is to enlarge the students' knowledge base and to motivate them to design new technical systems by combining and creatively using standard components.

In order to survey and improve our educational approach in functional analysis we are interested in how students gain insights while analysing technical systems. This raises two questions. (Q1) Which previous knowledge is required to single-handedly be able to fully understand how a specific system works? and (Q2) How can we support students in drawing special attention to the relevant components and the areas revealing their role within the system? For the purpose of answering these questions, we conducted a mobile eye tracking study, comparing high- and low-performing students.

The glasses-integrated mobile eye tracker rises no restrictions in the body position. This allowed the participants to move freely while operating with the examined object. In the experimental science, an examined object is also called stimulus. The used stimulus was a small, manually operable, but difficult to understand technical system. It could be disassembled in order to investigate all system components and it could be manipulated to observe how they interact. The subsequent eye tracking data analysis, both qualitative and quantitative, focused on the similarities and differences of high- and low-performing students. Based on the findings, recommendations for the basic engineering design education are presented by answering both research questions.

2 BACKGROUND INFORMATION

This chapter presents background information to facilitate the access to the subsequent chapters. It is divided in two sub-chapters: the functional analysis as theoretical background and eye tracking as the primary used tool for data acquisition in the presented study.

2.1 Functional analysis

Functional analysis. Viola, Corpino, Fioriti & Stesina (2012) describe that this method aims to break down a system into its basic functions and to map them to potential physical components for realisation. The results of the functional analysis are presented as a top-down functional tree and a bottom-up product tree which represent complementary views. Both views are fundamental approaches to analyse systems that are difficult to understand by subdividing them into parts. This promises to help developing new product concepts with a deep analysis of the requirements and to motivate the search of alternative solutions. This method cannot only be used for developing new technical solutions but also to analyse systems starting with the product to find the realized functions.

The functional analysis is not uncontroversial as a method to design new systems. Kroll (2013) states that the functional analysis needs a development of a solution independent function structure in the designing process which is difficult to apply. Furthermore, he criticises that the method may lead in a designing task to illogical combinations of sub-concepts.

Alternative analysing methods. The functional analysis provides a framework to analyse both, an existing and a novel product. The challenge is to find the basic functions of the examined product. In literature, there are several methods to gain this necessary information. This section focuses on two widespread analysing methods. Pahl & Beitz (2003) suggest analysing forces and motion in mechanical systems along the flow line of force analogue to flow lines in fluid mechanics. Matthiesen & Ruckpaul (2012) picked this approach up and exceeded it. The C&C^2 approach adds connections to the environments and to other structures to consider their influences and interactions. Both methods abstract the function structure while a reference to the embodied design remains.

Function-behaviour-structure framework. Gero & Kannengiesser (2002) present a framework of the fundamental processes in designing – the function-behaviour-structure framework. Here, a function is at first translated to an expected behaviour in the synthesis process. This expected behaviour is subsequently transformed to a structure in the so-called synthesis process. In the analysis process, the actual behaviour is reasoned from this structure. The actual behaviour is then compared to the expected behaviour in the evaluation process. Especially the analysis and the evaluation processes are directly connected to the functional analysis and provide a cognitive model. They describe how information from the external world are interpreted and compared to the expected information in the designer's inner world.

Comparison expert & novice. Expert and novices are compared in different fields like engineering, architecture, medicine and natural science. Jarodzka, Scheiter, Gerjets & van Gog (2010) examine how an expert's analysis process differs from a novice's in perceiving and interpreting information of complex, dynamic visual stimuli in the field of biology. They can show that experts use knowledge-based shortcuts by connecting observations with related information of their own knowledge. Further, experts focus more on relevant information than novices, which leads to faster performances. Harrison, Kim, Kou, Shum, Mariano & Howard (2016) compare the performance of an expert and a novice in an ultrasound-guided regional anaesthesia using mobile eye tracking. Like Jarodzka et al., they observe that experts solve tasks faster than novices and that the expert focus more on the relevant objects while the novice differ between relevant and non-relevant areas. Demian & Fruchter (2006) and Deken, Kleinsmann, Aurisicchio, Lauche & Bracewell (2012) observe the interaction between experts and novices in the field of architecture/engineering/construction industry and in the field of aerospace. They find that experts connect presented design tasks with past solved ones including the context to understand the design as a whole to apply this to the current situation including the assessment of the solution space.

2.2 Eye tracking

Why & How to use eye tracking. Bojko (2013) states that eye tracking is able to obtain qualitative and quantitative insights into user's cognitive processes. Further, it helps to unveil often-not-fully-conscious processes that led to the user's behaviour**.** Raw data is captured by video cameras detecting reflexions of infrared light emitted on the eyes and the eyes' pupils. The reflexions stay approximately in the same position, but the pupils move with the eye movement, both seen from the perspective of the video cameras. From the relative position of the reflexions and the pupil of an eye, an algorithm is able to calculate the view angle for a specific point in time, the so-called gaze point. The algorithm additionally divides the gaze data in events of fixation (eye relatively motionless) and saccades (eye moves to next fixation). This gaze data can be analysed subsequently with an area of interest (AOI) analysis. An AOI represents the participant's focus in the respective field of vision. AOI specific values show the perceived importance of single AOIs (Bojko, 2013).

Eye tracking in education. In literature, there are several examples of how eye tracking is utilized in education. It is employed in high schools (Gomes, Yassine, Worsley & Blikstein, 2013) as well as in universities (Jarodzka et al., 2010), (Mussgnug, Lohmeyer & Meboldt, 2014) and across disciplines (e.g. biology (Jarodzka et al., 2010) or engineering (Mussgnug et al., 2014)). Eye tracking aims at improving the design of education by examining how experienced students or experts perform in field-specific challenges (Jarodzka et al., 2010), (Gomes et al., 2013). Gomes et al. (2013) analyse high school students with an eye tracking system while they play engineering competence specific computer games with different difficulty levels. Here, the students have to change the initial, non-functional state of a mechanical system into a functional state. The goal is to find different eye tracking patterns of high and low performing students. Mussgnug et al. (2014) discuss how eye tracking can be used with different group sizes (>20p, 3-20p, 1-2p) and what kind of knowledge can be imparted to students, when using eye tracking as an educational tool.

Additional verbal protocol. Gaze data alone is not sufficient to conclude to a person's train of thought. Using additional, gaze-independent source of data helps to close this gap. One suitable tool for eye tracking is a verbal protocol (Bojko, 2013). If it is aimed to receive information in the functional context, Ruckpaul, Fürstenhöfer and Matthiesen (2014) recommend using the concurrent reporting (during performance). If metacognitive information is sought, they recommend cued retrospective reporting (after performance). In cued retrospective reporting participants use their own gaze video to report their train of thought. Further, they show that concurrent reporting has no influence on the participant's gaze.

3 METHOD

In the following, the study's implementation, data acquisition and data analysis are presented. The mobile eye tracking study was conducted with 12 mechanical engineering students (six Bachelor of Science students, six Master of Science students) to examine the functional analysis behaviour of mechanical engineers. It was aimed at searching for differences based on gaze data between successful and non-successful students.

The stimulus of this study was an original turning unit of a sun-blind. This unit adjusts the blade angle in three positions (opened, semi-closed, and closed). All unit components are presented in Figure 1.

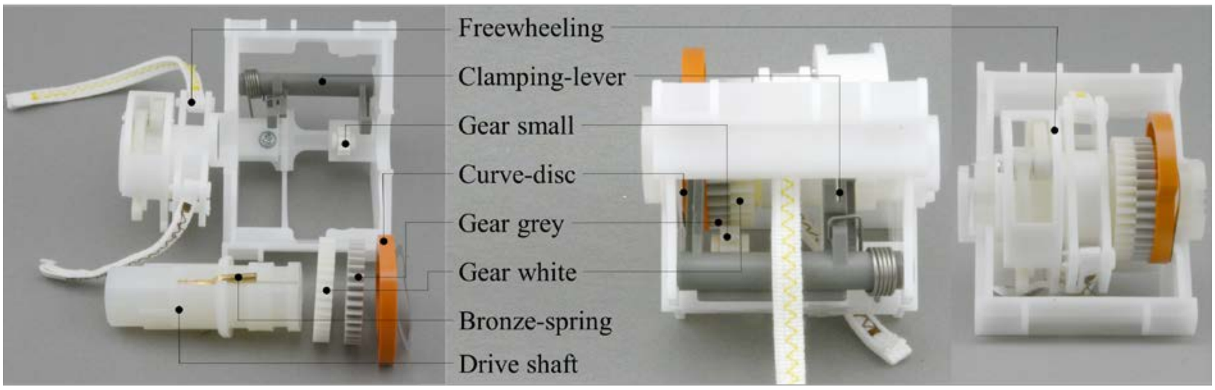

Figure 3. Components of the sun-blind turning unit with one disassembled unit (left) and one assembled unit (right)

Constant start conditions. A video presented the task and additional information for constant start conditions to all participants before starting in the functional analysis. The participants' task was to understand the delayed tilting mechanism of the presented stimulus. The additional information ought to facilitate the start in the functional analysis of the stimulus. It contained its turning function as described above, the attribute of lowering with the blinds turned in semi-closed position and that the unit tilts the blinds to the full-closed position with the 34th turn of the drive shaft. The searched mechanism for the sun blinds includes a relative movement of two gear wheels, initiated by a different number of gear wheel teeth. This relative movement finally triggers a curve-disc that activates a free-wheeling mechanism, which turns the blinds (see Figure 1).

Study implementation. The participants could use two units of the stimulus for the functional analysis and a pen to mark components. One unit was assembled and could be used to examine how all components move together. The other unit was demountable as it is presented in Figure 1 on the left-hand side and could be used to find hidden components (e.g. bronze-spring) or to examine components' characteristics. To decrease the participants' stress level, they were informed that there was no time limit. It was their decision when they finished the functional analysis. However, to not temporally exceed any reasonable analysable datasets, the experiment was stopped by the moderator if the participant did not manage to fully find and understand the searched mechanism within 20 minutes from start-time. The participants stood in front of a table during the analysis process. One challenge with mobile eye tracking occurs when participants lead the stimulus near to their body. This entails that they look underneath the eye tracking glasses. The result is a tracking error because the needed eye characteristics (pupil and reflexions from the infrared light) cannot be detected any longer from the eye tracking cameras. Pilot studies, conducted in advance, showed a lower tracking error rate when participants stood and did not sit in front of a table due to a subconscious slightly higher gaze point referring to the scene view. The standing procedure also seemed to lead to a higher level of concentration. Additionally, the two units were placed on a pad. The pad was placed in the middle of the table and served as an orientation for the participants' handling space. This also led to a lower tracking error rate.

Data acquisition. The participants' system analysis process was tracked in first person perspective via the SMI Eye Tracking Glasses 2 Wireless with a sampling rate of 60 Hz and a tracking accuracy of 0.5° over all distances. The eye tracking glasses have three frame-integrated cameras. Two cameras are directed at the user's eyes. Combining the information of the pupil's position with the relative position of the reflexions from the infrared light emitting sources, an internal computer chip in the eye tracking glasses is able to calculate the user's raw gaze point data (see Figure 2). This gaze data is subsequently processed by the integrated algorithm of the BeGaze software into the three events saccade, fixation and blink. This categorized data is combined with images of the scene view from the third video camera on the front side of the eye tracking glasses. This can directly be used to show the participant's gaze path for a qualitative analysis or for a deeper quantitative analysis of underlying correlations. As an additional source of information beside the eye tracking data, the participants were asked to think aloud to get an access to the participants' inner train of thought during the functional analysis process. To encourage the participants to do so, the moderator served as a passive contact they could speak to. In cases when participants forgot to think aloud, the moderator remembered them to do so with a short hint.

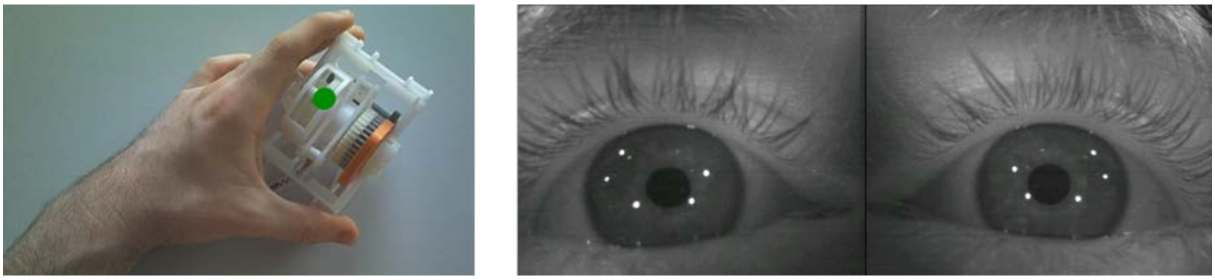

Figure 4. View from the scene view (left) and view from the eye cameras with reflexions (right); the dot in the scene view (on the freewheeling) represents the current gaze point, calculated with the information of the position of pupil and reflexions in the right image.

Qualitative data analysis. In the subsequent data analysis, the study data was at first analysed qualitatively. Based primary on gaze data and supplemented by think aloud audio data a participant-analysis-protocol was generated. The protocol contained a description of the participant's functional analysis in 30-seconds steps. It marked the participants' moment-specific analysis focus, their actions and if certain functions were understood or not. The layout of the protocol was icon based with a specific icon for every subfunction. This helped to compare the analysis focus path of different participants in parallel. Further, the protocol differentiated between analysing phases with incomplete comprehension of subfunction and phases of insights. This differentiation allowed to follow the insight path of all analyses and to find gaps but also jumps in it. This information enabled to find the participant's main moments of insight and gives an overall impression of how the particular participant went through the understanding process of the presented stimulus.

Quantitative data analysis. The quantitative data analysis focused on the characteristic of the AOI specific dwell time. AOIs of this study were the main-components of the stimulus (see Figure 1, left-hand side). To start with the quantitative data analysis, one intermediate step is needed since there initially is no direct link between the gaze point and the AOIs looked at. To connect the gaze point to the related AOI and thus the information what a participant gazed at at a specific point in time, a method called Semantic Gaze Mapping was conducted. With this method, the dynamic stimulus of the mobile eye tracking video is manually transferred into a static stimulus of a picture (see Figure 3) by linking one specific fixation to its related AOI. Using the SGM method, two difficulties may occur. First, when AOIs are small or allocated near to each other, sometimes it is hard to decide which AOI is related to the specific gaze point. In those cases, one has to define rules describing the right approach. Second, the gaze point is calibrated to a specific distance. If objects are looked at in a different distance than the calibrated one, the presented gaze point is not in the right positon. For closer objects, the gaze point is presented too far downright and for further away objects accordingly too far upper left. This is a mobile eye tracking specific issue and has to be considered and corrected in the data analysis. After this intermediate step, the AOI-time-relation is made and can be illustrated as an AOI-Sequence Chart (see Figure 3). The start-point (t=0) represents the participant's analysis start. This visualisation of ET data was used to find links among single AOIs defined by the participant's gaze and hence to deduce on the participant's analysis focus.

Combined data analysis. The combination of the qualitative and the quantitative data analysis results was performed to identify the participants' main moments of insight in the quantified gaze data and highlight them. The necessary highlighting step was performed combining the AOI gaze data from the quantitative data analysis with the moments of insight from the qualitative data analysis. The AOI gaze data were selectively blanked off so only the moments of insight remained (see Figure 3). The combined data analysis focused, based on this intermediate step, on characteristic values of the participants' insights. These values are the sequence, the concentration, the complexity and the number of the insights. To find similarities and differences in the analysis, the results of these characteristic values of the two participant groups are compared.

4 RESULTS

In the functional analysis, 6 out of 12 participants succeeded and fully understood the presented stimulus. They are following called high-performers. The other 6 participants did not fully understand the presented stimulus and are following called low-performers. In each group, the gaze data set of one participant was qualitatively not sufficient enough to be analysed. Consequently, the data sets of 5 high-performers and 5 low-performers were analysed.

Figure 3 respectively shows the Moment of Insight AOI Sequence Chart of one representative successful participant P1 (left) and one representative non-successful participant P2 (right) over their complete analysis process. Participant P1 completely understood the function of the turning unit in approx. 16 minutes. The moderator stopped the analysis process of participant P2 after 20 minutes.

Success criteria. Five subfunctions have to be recognised and understood to fully understand the function of the sun-blind turning unit. In the following, these five subfunctions are listed according to the flow line of force. The subfunctions 1-4 together effect the mechanism of the full-tilt delay and had to be understood to be counted as successful. Subfunction 5 completed the functionality of the sun-blind turning unit and was the exit of the flow line of force from the analysed system. This subfunction was not necessary to be understood to be counted as successful (compare to Figure 1 for the specific parts).

1. relative displacement of gear-wheels (gearing mechanism causes unequal revolution speed)
2. freeing of bronze-spring (combination of hollow in grey gear-wheel and relative displacement)
3. triggering of curve-disc (bronze spring gearing into recess of curve-disc)
4. triggering of freewheel (curve-disc removes disabling-lever)
5. activation of freewheel (disabling-lever invalidates freewheeling & attached cords turn blinds)

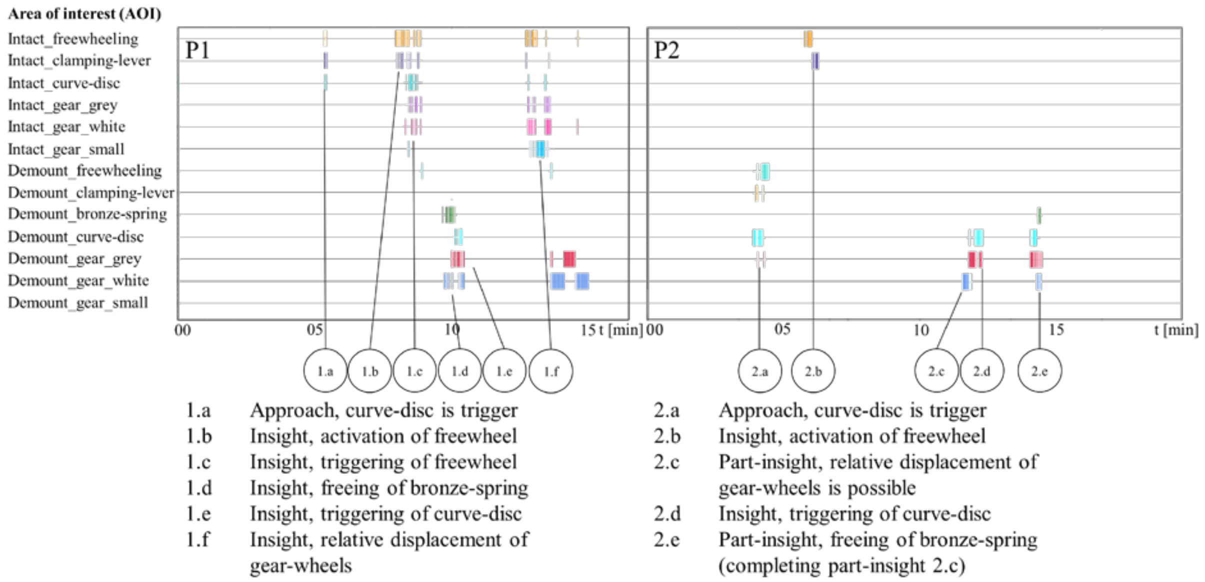

Figure 5. Moment of Insight AOI Sequence Chart of a successful (left) & a non-successful participant (right) with the specific insights of the respective participant

Group independencies. In the study, six students with a Bachelor's degree and six students with a Master's degree were analysed. No relation between the education level and success in the functional analysis of the presented system was found. The twelve students were equally distributed in both groups of high- and low-performers. All twelve students were taught in functional analysis in during their basic engineering education. No group-specific pattern was found as well respective the sequence of insights. Participants started at different subfunctions, no matter if high-performers or low-performers. This led to different sequences of insights regardless if the analysis was successful or not.

Analysis similarities. Concerning the moments of insight in general, both high- and low-performers showed similarities. In these short time spans (approx. 10-50s), the related AOIs were gazed at predominantly and formed an insight-pattern (e.g. Figure 3, 1.a).

Analysis differences. Differences in the insights between high- and low-performers were the frequency, the complexity in terms of the combination of insights and the number of insights. Regarding the insight frequency, Figure 3 shows a characteristic difference between a high-performer (P1) and a low-performer (P2). Although participant P2 had his first insight earlier than participant P1, he stumbled and had a long period with no insight (2.b to 2.c). In contrast, participant P1 has a higher insight frequency, starting with insight 1.b. The insights 1.b to 1.e appeared within approx. 150 seconds. This is characteristic for high-performers. In the start-up phase, they collect information and slowly create an image of the system. In the end phase, one insight triggers the next and all relevant subfunctions are connected to each other. Relating to the insight-complexity high- and low-performers also showed differences. High-performers often correctly combined the information of one observation with another one received before. For example, participant P1 understood that the movable grey gear frees the bronze-spring when it is turned to the key-position (gear-wheel-hollow over bronze-spring, insight 1.d), remembering the discovery of the bronze-spring minutes ago. In contrast, participant P2 needed two attempts to fully understand this subfunction (insight 2.c & 2.e). The main and crucial difference between high- and low-performers were the number of insights. All low-performers missed the insight how the relative gear wheels displacement works. The gaze data of the low-performers showed no insight-pattern with the small gear included (representatively see Figure 3, right-hand side). This component is essential for the resulting relative movement in the gearing mechanism. Some low-performers observed the relative movement of the grey and white gears and took it as given. Other low-performers broke the analysis off because they could not find its origin.

5 DISCUSSION

As introduced, the two research questions of this paper were (Q1) Which previous knowledge is required to single-handedly be able to fully understand how a specific system works? and (Q2) How can we support students in drawing special attention to the relevant components and the areas revealing their role within the system? Based on the results of this study we would like to answer both.

Answering Q1. Generally speaking, a wide knowledge base is required to single-handedly be able to understand how a system works. It helps to perform two important steps in the functional analysis. Firstly, it enables to connect an observation with a related fact in the owner's memory, a so-called knowledge-based shortcut [5]. Many high-performers combined the observation of the gear wheels' relative movement or the unequal number of gear wheel teeth and the engagement in the small gear wheel with their knowledge of a strain wave gearing. This knowledge enabled them to understand the function of the relative displacement without having examined it in detail. Oftentimes, it triggered the action of counting the gear wheel teeth to verify this assumption (see Figure 3, insight 1.f). In contrast, the results of the data analysis show that no low-performer could estimate the function and the importance of the small gear wheel. Many assumed that its function is to underpin the two other gear wheels. This result indicates that they were unaware of a possible relative displacement realisation by a different number of gear wheel teeth combined with an equal gear wheel diameter (white and grey gear wheel, see Figure 1). Secondly, a wide knowledge base helped to identify and to evaluate the relevance of a system's subfunction. In the study, the understanding process of the freewheel was a time-consuming analysis part. Although almost all participants managed to understand its function, some needed nearly half of their analysis time to comprehend this aspect. In some cases, this led to an abortion due timeout. Hence, the ability to recognise this function and to assume that it is not related to the searched mechanism helped to prioritise the analysis focus on the gear mechanism and to save time. Consequently, presenting in the basic engineering design education many examples of realisations of standard and of complex functions helps to develop a required knowledge base. Especially examples of unorthodox usage of standard components in everyday products (e.g. toys, tools, etc.) shows the variety of mechanical mechanisms. This enables to connect the knowledge of an abstract function like a freewheel with its possible realisations and to know different functionalities of standard components (e.g. gear mechanism or springs).

Answering Q2. It needs an overlaid analysis strategy to gain a structure and thus reliability in the functional analysis aside the recognition of subfunctions and subsystems based on the comparison to the own knowledge. It is important that basic engineering design education imparts this mindset to the students to improve their ability in functional analysis. The data analysis showed that low-performers did not consequently follow the flow line of force in and out of the system but rather trusted in their own assumptions without checking them. This partially led to irritations when they found facts which did not go well with their assumptions and thus sometimes led to an own defined abortion of the functional analysis. High-performers on the contrary checked their analysis-status by following the flow line of force from their individual starting point to their current end. With that, they found gaps in their own defined flow line of force and they searched for the following subfunction to be understood. Guided by this trail, they connected functions of subsystems or components to adjoining subsystems or components. According to the data-analysis results, it has no influence on the understanding success with which insight the participants started. Consequently, using analysis-strategies like the discussed one helps to identify relevant components and to understand their role within the system. For this reason, it is important to train students in basic engineering design education in such analysis strategies and show the meaningfulness of such approaches. Further, it needs practice to learn such analysis-strategies. The results of this study show that time in education for itself guarantees no success in challenges like the presented one. Contra expectations, the Master's students were not more successful in this challenge than the Bachelor's students. The equally distribution of the students in both groups of high- and low-performers indicate that some Master's students focused in their education more on different fields than design and development where functional analysis is an important ability. This indication supports the approach to support and encourage students to practice functional analysis with technical systems by giving them the opportunity to do so in their basic engineering design education.

Limitations. The dominating limitation of this study is that the analysis-processes of only one stimulus could be compared. Further limitations are the number of participants and the mobile eye tracking technology. Although the data-analysis rises comprehensible results, comparing two groups with five members each allows no definition of a general rule. Considering the highly individual analysis process further investigation is advised to strengthen this study's results. The mobile eye tracking technology rises the limitation of the so-called parallax error. This error occurs when the gazed object is not in the calibrated distance from the participant. If the analysist is not aware of its occurrence, the wrong AOI is related to the current gaze point. As well, the AOIs of this study themselves reveal as a limitation due to the small diameter, especially when the size of the AOI is smaller than the precision of the eye tracking system (0.5°). To compensate this issue, argumentation is not connected to single AOI-hits but to AOI-cluster and combined with think-aloud data.

6 OUTLOOK

The insights and learnings from this study lay in two fields. First, this study motivated us to develop new methods to analyse the eye tracking data. Second, it encouraged us to follow and to extend our approach in imparting the functional analysis.

The combination of qualitative and quantitative analysis of the eye tracking data led to a more intuitive visualisation than a standard heatmap or the gaze video which allowed to compare several participants at the same time in parallel. This approach shall be further developed in the future. In the preparation phase for the data analysis, the intermediate step of Sematic Gaze Mapping to connect the gaze point to the looked at objects needed a lot of time. The proportion of video time to analysis time laid in a range of four to ten. Currently, we develop methods to automate and semi-automate this intermediate step with approaches from the computer vision and artificial intelligence. The goal is being able to analyse the eye tracking data fully automated. This shall enable us to use mobile eye tracking in a 90 minutes lecture workshop from scratch, developing the test setup, conducting the test cycle and finally analysing the eye tracking data subsequently.

We conducted this study to survey and to improve our educational approach in functional analysis. As discussed before, presenting a wide range of mechanical mechanisms in everyday products helps to develop a knowledge base, which can be referred to in a functional analysis. Further, imparting the mindset of using strategies in functional analysis is important so students gain structure in analysing technical systems. This motivates us to follow this track presenting many examples and exercising the application of analysing strategies in lecture. Currently, we extent this approach in our basic engineering design education lectures. Students analyse parallel to the lectures in an accompanying workshop predefined or self-chosen technical systems in small groups. Subsequent, they present their analysis results to their 500 fellow students and lead them systematically through the functional analysis. We expect a deepened knowledge and a higher motivation to go systematically though a system's functional analysis by the students. Further, we also expect a higher level of acceptance of this analysis method by the students when their fellow students show a successful result of this approach.

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Design thinking, the value of collaboration, the importance of context … serendipity in research threads

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Erik Bohemia, Loughborough University, UK

Unlike the Guest edited section in this issue, articles in the general section have not been submitted with a particular theme in mind. However, whilst those in this issue are from an incredibly diverse range of contexts, there are, by happy chance, some clear threads running through. Design thinking features in one way or another in all research articles, whether the focus is on six year olds collaborating in a design task, considering university- industry links or using design thinking as a lens for problem based learning. Throughout the articles there is also a focus on collaboration – sometimes in the context of design thinking, but also in exploring the value of team approaches and of professional collaborations that support the development of design education curricula. Finally, there is a strong thread of the importance of embedding design and technology activities in relevant contexts, whether working with marginalised communities in India or innovative designing in the context of maternal and neonatal care in the United States.

The DATE journal prides itself in its broad and inclusive approach to research in Design, Design and Technology and Technology Education across age ranges spreading from early years learners to postgraduate students. The belief is that all that are interested in nurturing design and/or technological capability can share and learn from each other. Taking together the articles selected by our guest editors and those in the general section, we hope you find that this issue responds to this belief.

In keeping with tradition, we begin with a reflective piece from Richard Kimbell. In 'Cycles' he reflects on the cyclical ways in which history develops, seeing the rise and fall of empires, cultures, ideas and so on. His particular focus is on the cyclical rise, and now fall, of take up for public examinations in Design & Technology. Reflecting on the history of the subject, he encourages teachers to seize the opportunity and regain control of the heart of the subject in moving forward to a new phase in the cycle.

We then move the research section with an article focusing on how six-year-old children collaborate during designing. In their article *Peer collaboration of six-year-olds when undertaking a design task,* Virpi Yliverronen (University of Helsinki), Päivi Marjanen (Laurea University of Applied Sciences) and Pirita Seitamaa-Hakkarainen (University of Helsinki) focus on children's verbal and embodied interactions alongside the social roles visible when collaboratively designing. Using

Vygotsky's theory of sociocultural learning they track the interactions of the children, which indicate that they can successfully collaborate whilst solving problems and that embodied expression plays a notable role. The article provides a broad backcloth of related research with young children and situates their own research in the context of Finland where craft, along with design and technology, is very much part of the school curriculum. Analysing video recordings of children working in teams, they created a classification schema categorised through verbal collaboration and embodied collaboration. Highly detailed analysis is presented that illustrates the nature of design discourse and quality of interactions and abilities of young children when working collaboratively. These insights provide excellent illustrations for educators working at all levels of education, reminding us of where nurturing design capability starts and what can be built on.

Resonating with articles presented in the Guest edited section, Amaltus Khan and Puneet Tandon (PDPM Indian Institute for Information Technology, Design and Manufacturing) discuss *Design from Discard: A method to reduce uncertainty in upcycling practice*, proposing "Design from Discard" as a new method to help designers conceptualise products that genuinely meet stakeholder needs by upcycling materials from discarded waste. In their research, they worked with interdisciplinary teams of Masters level design students from backgrounds in mechanical engineering, electronics and communication engineering, industrial and product design and computer science engineering. They focus on research gaps in upcycling, such as how 'discards' should be handled and the multiple considerations in upcycling, such as incorporating marginalised communities. Working from stakeholder interests and customer preferences, the students worked through an iterative process, focusing on Draw, Identify, Split, Correlate, Associate, Rectify, and Deliver that, collectively, create the acronym 'DISCARD'. Providing detailed insight into the process, and illustrating this through case study, the research indicates how the approach supports handling uncertainty and brings a clear focus on usability. The article provides a strong illustration of designers working within a distinctive contextual situation and the value this brings for the relevance of the work undertaken.

The next article focuses on a very specific context– that of designing medical devices. Jules Sherman, Henry C. Lee, Madeleine Eva Weiss and Alexandria Kristensen-Cabrera (Stanford University) present a fascinating study *Medical device design education: Identifying problems through observation and hands-on training.* A comparative research project involved two groups of students, with a shared focus on design thinking but where, for one group, an experiential, hands-on learning pedagogy was adopted, while the other focused observational learning. The groups were multi-disciplinary (engineering, design, medicine, business, law, humanities, education, earth sciences) and multi-level (undergraduate and post graduate), with co-teaching by a design academic and medical clinicians. Both groups were focused on acquiring and synthesising knowledge and understanding towards medical design innovation in the context of maternal and neonatal care. The students were immersed in the context by being provided initially with information on maternal haemorrhage and infant resuscitation and through being on-site in the neonatal unit. The study revealed that, while the quality of ideas and execution of both groups were similar, those that had hands-on experience during the course showed a higher level of excitement. Moreover, the study provides detailed insight into the positive impact of multidisciplinary students having an in-depth immersion in both the specific context for which they are designing and in a design thinking process.

Continuing the thread of design thinking, Heilyn Camacho, Mette Skov, Tanja Svarre and Thomas Ryberg (Department of Communication and Psychology, Aalborg University) provide an article entitled *Pathway to support the adoption of PBL in Open Data education*. This article may not be an obvious one for the Journal, as it focuses on teaching and learning Open Data (OD) from a Project Based Learning (PBL) perspective. But it offers those interested in design and technology education at any level of education extremely useful and interesting insights into the pedagogies of OD and PB through a lens of design thinking, including a focus on the teacher as designer. Based on research undertaken by a research consortium involving Greece, Malta, the UK, Belgium and Denmark interviews were conducted to help understand teaching practices in OD and PBL. These provided insights into what were perceived as successful teaching practices, such as focusing on relevance, hands-on exercises and sharing competences within a learning group. They also identified a set of challenges, such as the complex and abstract nature of OD and a lack of experience in teaching OD, a relatively new area. A workshop was conducted which revealed, amongst other things, the importance of teacher as designer. For design and technology education communities, the article is particularly useful in providing insights into pedagogies of problem based learning and their link with design thinking and the teacher as designer, alongside some very helpful background on Open Data teaching initiatives.

Finally, Onder Erkarslan and Zeynap Aykul (Izmir Institute of Technology) present their research in *Review of Curriculum Development for University-Industry Collaborations with a Comparative Analysis on Master of Industrial Product Design Education*, which focuses on university-industry collaboration in a comparative analysis of the curriculum of a Turkish and a Swedish university. To undertake the comparative analysis, two approaches were taken; first to compare curriculum and second to conduct a survey with design industries. In the curriculum analysis, there was a particular focus on professional design practice, design studies and design thinking. The survey was structured through questions about the company itself and then on what companies expect from graduates. The study identified a need to develop the curriculum to include more teamwork and innovative and collaborative activities and more development of design thinking characteristics. The article indicates the value of exchange of ideas between universities, particularly when linked to detailed analysis of curriculum. Early in the article the authors raise the issue of industry involvement brings too much instrumentality to the learning. While the industry survey did show an expectation mismatch in relation to technical skills and project management, what they were keen to see being developed were teamwork and concept development – a further indication of the value of dialogue between interested partners.

To close this issue, Wendy Fox-Turnbull (University of Waikato) has reviewed a new book by Gill Hope, *Mastering Primary Design and Technology*. The book is in the Mastering Primary Teaching series, published by Bloomsbury Academic.

Cycles

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The social history of the world is written in cycles. The Roman empire began with Cicero and the Republic before 50 BC, grew to the height of its power in the 2nd and 3rd centuries AD and was pretty much finished by 450 AD. The Viking raids on the English coast began about 790 AD. At the height of their power, two of their leaders claimed the English throne (one being Cnut of tidal fame) about 1020, but by 1100 their raiding days were over, they settled and intermarried to become just another part of our DNA tapestry.

The technological world demonstrates the same cyclical trend. The battle of Crecy (1346) heralded the rise of the English longbow, and by Agincourt (1415) it was such a dominant weapon that Henry Vs 6000 men largely obliterated a French army of 25,000. It is estimated that 10,000 died in half an hour. But by 1650 the weapon was largely out of use, having been supplanted by muskets and cannons. And these in their turn were on a cyclical path of evolution. By Trafalgar (1815) British naval strategy had evolved around the destructive power of the muzzle-loading cannon, but a hundred years later they were all gone, being replaced on the 1st World War battlefields by howitzers and 'superguns'. In more peaceful mode, the first recorded example of a windmill (on the Nile) is from about 5000 BC, but they emerged in Europe in about 1200, and by 1850 there were thousands of them, but they in their turn were progressively supplanted by other technologies – notably the steam engine.

If I was tempted to develop a theory of progress, it would start from something like 'there is no such thing as permanence' … or perhaps … 'the only permanence is change'.

It is – we might think - all very well for historians to take such a cool and dispassionate view of things, but it feels very different when one is enmeshed in the midst of one of those cycles. When long-bowmen saw the power of firearms they must have been in despair. Their world was falling apart. And whole libraries of despair have been filled by the passing of civilisations, notable among which is Gibbon's 'Decline and Fall of the Roman Empire'. We all live within a moment in time – we are on the inside - and as the wheel of fortune rolls around, it is (I think) quite normal to feel progressively displaced and discarded by later evolutions. And, of course, we curse the circumstances (including the politics) that have brought us to this sorry state.

It is time to come clean and declare that this particular set of musings has been prompted by the recent publication by the UK Office of Qualifications and Examinations Regulation (Ofqual, 2018) of data concerning GCSE examination [5] entries for England 2018, for there is another cycle at work

[5] GCSEs are General Certificate of Secondary Education public external examinations, taken typically by 16 year olds

here. In the 1980s and 1990s Design & Technology was in a growth phase but the latest figures now appear to confirm a trend of decline.

On page 4 of the report, we read that the examination entries for Design & Technology have fallen from 127,000 in 2017 to 117,000 in 2018. Colleagues at the Design and Technology Association and elsewhere have been keeping an eye on these figures for a long time. They are in fact quite hard to compute as the examinations keep changing and of course the cohort size also keeps changing. So perhaps the best way to represent these data is as percentages of the population that might/could take it. I could not swear to the accuracy of the minutiae of these data – but the trend is revealing, and one way to demonstrate it is to look at a sequence of decades.

1988 = 36%

1998 = 53%

2008 = 43%

2018 = 22%

The millennium year of 2000 was a high point, where the figure was 58%. In that year, the Design & Technology International Millennium Conference in London was reported in a conference volume that I edited. There were 38 papers with authors from Australia, Canada, Israel, Netherlands, New Zealand, Spain, Taiwan, UK and USA attesting to the influence of design & technology worldwide. But if that was a high point, there is little room for doubt that the current year represents the lowest figure, and of course there are many reasons for it, primarily the emergence of Gove's Ebacc[6] that excludes not just Design & Technology but all creative disciplines. Added to that is the widespread deconstruction of the National Curriculum, and of teacher education establishments, and of Local Education Authorities; and the gradual replacement of the idea of a national education service with one of a de-centralised (fragmented) service increasingly dominated by independent Multi-Academy Trusts (MATs). In a few decades time, someone will write the history of this period – and it might look a bit like Gibbon's, where a combination of ideology and incompetence brought a whole civilisation to its knees.

There are of course many ways to respond to this set of circumstances. But despair is such a wasteful emotion that there must be a better response than that. So, I was pondering a few questions that – to me – appeared interesting and likely to lead to a more profitable outcome.

[6] Michael Gove, the UK Government's Secretary of State for Education (2010-2014) introduced a new performance indicator in 2012, called the English Baccalaureate (Ebacc). This indicator measures the percentage of students in a school who achieve one of the top 4 grades (out of 9) in five or more GCSEs in English, mathematics, two sciences, a foreign language and history or geography. This performance measure (of schools and students) controversially excludes all creative and performing arts and design subjects.

What did the Romans do after Rome had 'fallen'? What did the Vikings do after they had exhausted their rounds of rape and pillage? The Romans in Britain did not just cease to exist. They evolved and, in the process, helped to shape the British nation. Similarly, when King Harold defeated the Vikings at Stamford Bridge in 1066, they didn't just disappear. They settled, intermarried, and gradually morphed into Danes, Swedes, Norwegians, Icelanders, Greenlanders – and of course Brits. And surely their greatest influence on Britain was through their prowess as international travellers and traders. It is easy to see this as the roots of our distinctly British sea-faring tradition. Shoal, gale, keg, keel, wake, oar, rudder and bilge are all Viking words.

So rather than fret about what might be in decline, lets rather think about what comes next. We would do well to recall the sub-title of the Millennium Conference: "Learning from experience … modelling new futures". It has never been a more important time to evolve and model some new futures, for there is no room any more for assumptions about our right to exist. If Design & Technology is to continue to exist in your school, it won't be because of national policy – it will be because the Head, the Governors, the senior team of managers, and parent representatives are persuaded that it makes a valuable and important contribution to the youngsters in your school. It comes down to every individual Design & Technology teacher. We are all now the bottom-line advocates for what we believe in. We must persuade and perform at the local level, because that is where the decisions are now being taken. We know that where departments' practice is strong the subject sells itself. Head-teachers are not daft and would not choose to close a department that has a strong public profile, a record of engaging events and hoards of excited youngsters talking about the fabulous things they are doing in the D&T workshops and studios.

And we do now hold one trump card that did not exist when Design & Technology was struggling into existence. The public awareness of design has never been higher than it currently is. Whole supplements of the Sundays are devoted to it and our television/media choices are rich in design options – not least Grand Designs. To understand and be empowered within our culture even head-teachers have to recognise the centrality of design. This is a valuable lever that we can use to enrich our arguments and our practice.

More than 32 years ago I was asked to write the national teachers' guide for the introduction of GCSE Craft Design & Technology (CDT) and I was very aware that we had just been through a frenetic period of curriculum evolution, and I argued that the emergence of Design and Technology reflected an interesting blend of chaotic individualism and centralised conformism.

Since that time – just prior to the National Curriculum – there has been a massive oversupply of centralised conformism. But that has now been eroded by national policy and the time has therefore come for another big dose of chaotic individualism. Some might see this as a problem, or even a crisis in Design & Technology. I do not. I see it as another moment for the creative body of teachers to stand up and be counted. Schools should feel free to evolve their Design & Technology curricula in whatever way they believe will work best in their school and in their community. And if Design and Technology ends up looking a bit different here and there – so be it. Just as Design & Technology was different from the Craft, Design & Technology (CDT) it replaced.

> ... if the steady growth and development of CDT over the last twenty years has taught us anything at all, it is that to advance our thinking we must rely on the innovation and creative endeavour of teachers in the classroom ... without this possibility of innovation CDT will wither and die ... (p.42)

It didn't die, but – like the Romans and the Vikings - it morphed into another form that was more suited to its time. And now we find ourselves at another of those hinge moments when individual teachers and schools can make a serious difference to the future of Design & Technology. I concluded that 1986 guide with the following words.

> The issue here is the extent to which teachers regard the curriculum as fixed by others and given to them merely to implement; or conversely the extent to which they see their professional responsibility as including the continuous development of that curriculum.

I really hope that there are enough confident, cavalier, creative teachers out there who can grasp this opportunity and take us forward.

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Design and Technology Education: An International Journal

23.2

Peer Collaboration of Six-year olds when Undertaking a Design Task

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Abstract

The purpose of this study was to explore six-year-old Finnish preschoolers' collaboration during a designing session, where they received a task to collaboratively design and sketch forest animals' nests. Peer interaction is a natural part of craft, design and technology education because the learning situation itself provides various possibilities for collaboration. Craft making is traditionally seen as an individual execution, where makers are producing their own craft products instead of collaboration and shared outcomes. During this intervention, an experience of a shared designing and making situation was provided for children. The article focuses particularly on children's verbal and embodied interactions, as well as children's social roles in their groups, depending on their ability to use language during the designing process. Children's activities were examined within Vygotsky's sociocultural framework for learning and classified using a micro-level analysis methodology for tracking children's collaboration and meaning making in designing. The results showed that six-year-old pre-schoolers succeeded in working collaboratively and they managed to solve the designing task with their peers, but embodied expressions also played a notable role in designing. Four types of roles, which children had in their peer groups, were found.

Key words

preschool, peer collaboration, design and technology education, sociocultural learning, roles

Introduction

Interpersonal skills, including the tolerance to work together as well as the ability to listen and understand various opinions and different perspectives, are crucial skills in a culturally diverse world, in which young children are growing up (Finnish national board of education [FNBE], 2016; Sawyer, 2006b). These skills can be promoted through design education, which provides versatile opportunities for shared thinking and joint decision-making (Hennessy & Murphy, 1999). However, very little is known about young preschool-aged children's design and craft processes and how they work collaboratively. This study aims to partially fill the gap by examining and analysing the nature of six-year-old preschoolers' social interactions during a collaborative designing session, where they sketched floor plans for forest animals' nests. The designed floor plans were later constructed. Children's design activities were approached from Vygotsky's (1978) sociocultural framework. Working together in a collaborative learning setting is a recent theme in educational research, in curriculums and in practical work with young children (Kangas, Seitamaa-Hakkarainen & Hakkarainen, 2013; Sullivan & Bers, 2016; Sundqvist & Nilsson, 2018; Turja, Endepohls-Ulpe & Chatoney, 2009).

Interaction, self-expression and the ability to understand others play major roles in an individual's functional capacity and well-being. The sociocultural perspective on learning emphasises the role and meaning of peer interaction (Vygotsky, 1978), and the cultural and collective bases are highlighted in sociocultural theories of child development (Kim, 2014; Rogoff, 2003). Children are considered to be active agents who learn through acting and using language and semiotics. Preschool-aged children are typically attracted by the other children, and they usually enjoy their peers' company. Children construct their identity and adopt peer culture and social skills through participation in communities, where collaborative learning supports a learner's mental, social and emotional development (Hennessy & Murphy, 1999; Lillemyr, Sobstad, Marder, & Flowerday, 2011). According to Vygotsky (1978), language is a dominant psychological tool for seeing, talking, acting and thinking. Language is used to accomplish ways of representing ideas, interpreting experiences and constructing explanations. The most favourable conditions for learning and interaction are situations where children define a problem, test different alternatives to solve it by themselves with peers, and finally find a solution through action (Hennessy & Murphy, 1999).

A number of studies have investigated primary-aged children's interactions whilst working in peer groups from the viewpoint of social and cognitive processes (e.g. Butler & Walton, 2013; Chen, 2016; Lim, 2012). While some studies rely on collaborative activities, other studies are focused on children's language skills during collaboration, since verbal interaction constructs a shared understanding between interactors (Edwards & Mercer, 2013). Sociolinguistic methods, which view classrooms as interactional settings, have provided useful concepts and tools to analyse classroom interaction from the sociocultural perspective (Kovalainen & Kumpulainen, 2009). Kumpulainen and her colleagues have implemented several studies on the social construction of teaching and learning in pre- and primary classroom communities, aiming towards dialogic meaning making and joint creation of knowledge. These studies are focused on the areas of mathematics, early years' science-learning and cultural content in creative museum engagement.

Children's roles in adult-set tasks have mostly been studied from the viewpoint of leadership styles (Lee, Recchia, & Shin, 2005). Such roles as leaders (primary leader and supporting leaders) and non-leaders (quiet members) were defined, when children's leadership was examined in discussion groups in classrooms (Li et al., 2007). Some research has focused on the nature of relationships within children's spontaneous collaborative play. Mawson (2009) found two key roles, which he named dictators and directors, assumed within a group by individual children in situations where three-to-four-year-old children played without an adult's guidance. Ghafouri and Wien (2005) found four kinds of roles in four-to-five-year-old children's play. These were leading and following roles, supporting emotional well-being, collaborating by including others in play, and conflict resolution skills. Segal, Peck, Vega-Lahr and Field (1987) also considered those children who did not have a pivotal role in the group's dynamics, when they identified three social leader styles and two follower styles among preschoolers' group interactions during free play. Common among all of these studies is an observation of the importance of language in effective collaborative interactions (Fawcett & Garton, 2005).

All in all, previous studies have revealed the importance of peer interaction for children to learn collaborative skills, but also highlighted the difficulties related to verbal communication. The present study aims to describe young children's ability to work towards a shared goal in a designing task, where they had to solve the given task by discussing, drawing and cooperating. Craft making in an educational context is traditionally seen as an individual execution, where each of the children are producing their own craft products in a learning situation. During this intervention, we tried to avoid that kind of setting, and instead we provided an experience of a shared designing and making situation for children. Young, preschool children are just beginning to exercise collaborative skills, as well as many other skills for school and life. It cannot be expected that their collaboration is well-developed from the very beginning: at the very least, children need adults' scaffolding to achieve their common goals. Scaffolding (help, such as prompts and hints) from a more skilled person is a crucial part of the learning process (Ninio & Bruner, 1978). Thus, in the present study the nature of preschoolers' collaboration during the designing task will be investigated from the perspective of linguistic and embodied interaction. The specific research questions are as follows:

1. How does children's verbal and embodied collaboration occur in a collaborative designing session?
2. What kinds of roles did children have in their peer groups?

In the following, we will first discuss the importance of peer interaction and collaboration in early childhood and the nature of young children's design and technology education, then we will present our research setting, method of data collection and data analysis. Results and descriptions of pre-schoolers' designing activities will be presented as a conclusion.

Peer interaction and collaboration in early childhood

Peer group work is an essential part of children's everyday life, social identity and the building of skills needed in the future. In peer groups children learn together, learn to make compromises, learn to create their own space, and learn empathy and assertiveness. Working in a peer group develops children's skills to meet criticism, for example, when peers express their opinions. Peer groups also teach children to make social comparisons, which helps children to build self-perception (Marjanen, Ahonen, & Majoinen, 2013). Skills to negotiate, settle and solve disagreements are important developmental tasks, where children's skills will be refined and their abilities strengthened (Kronqvist, 2006). Peer group learning consists of shared goals, commitment, evaluation of actions and shared understanding.

Collaboration refers to a situation where students actively negotiate and work together to solve a problem or otherwise construct common knowledge for a shared goal (Hennessy & Murphy, 1999; Mercer & Littleton, 2007; Vygotsky, 1978) Successful collaborative working sessions with peers offer natural ways for scaffolding and supports deep understanding (Sawyer, 2006b). In kindergarten, collaborative action between children usually happens in informal situations, like play, frolic and games, where children must negotiate game rules. The peer groups may have a certain asymmetry (Verba, 1998), group members can express their feelings freely, challenge the peers' opinions and justify their points of view. Shared understanding is usually created through language, but communication might also be non-verbal. Since young children often lack words to express themselves verbally in social situations, they use non-verbal communication such as gestures and facial expressions (Verba, 1998). Embodied expressions are an essential part of young children's communication because they live, act and learn new things in a very holistic way. According to Capone and McGregor (2004), the development of gestures is closely related to the development of language skills and gestures enhance language development: gestures support spoken expression and help young children's concepts acquisition (Capone & McGregor, 2004). In this study, we defined a gesture as a visible bodily action that is used as a part of communication, such as pointing and depiction (Kendon, 2004; Kita, Alibali, & Chu, 2017). The distinct types of hand gestures are called representational gestures (Kita, Alibali, & Chu, 2017). In collaborative designing situations, hand gestures are considered to demonstrate children's thinking (Hall & Nemirovsky, 2012), like expressing ideas by pointing, nodding or shaking their head or making hand movements to express shapes.

Young children's craft, design and technology education

Craft has been a part of early childhood education since Fröbel's kindergarten ideology in 1800s (Kiviniemi & Vuorinen, 2010), but it's roles as a content of young children's education and kindergarten activities have varied a lot on decades. In Finland, craft tasks have been lately more like hobby crafts, or craft has been omitted and replaced with visual arts. Craft has, however, its own features, which cannot be replaced with similar kinds of activities. Craft education in early childhood education and preschool is a versatile combination of designing, inventing, experimenting and making, as well as science, technology and thinking skills (Finnish national agency for education [EDUFI], 2017; FNBE, 2016). Technology has quickly become a part of young children's lives, and because of this, educational purposes of technology have been emphasised in early childhood curricula in recent years (EDUFI, 2017; Sundqvist & Nilsson, 2018; Turja et al., 2009). The purpose of technology education in preschool is to help children understand everyday technology and how it can be used to solve daily life problems (Sundqvist & Nilsson, 2018). Robotics and programming are educational tools for cognitive- and fine motor skills, as well as for peer interaction and collaboration (Sullivan & Bers, 2016). They present new ways to implement craft, design and technology education and they are tools for integration with STEM (science, technology, engineering, mathematics). These new contents do not exclude traditional materials and techniques away from craft, but they are an extra tool for playful and experimental activity with peers.

Peer interaction is a natural part of craft, design and technology education because the learning situation itself provides various possibilities for collaboration. Hennessy and Murphy (1999) have introduced a framework for optimal preconditions for collaboration in design and technology education. The strength of design and technology education is in its ability to combine procedural problem-solving activities to talk and provide feedback with peers and generate concrete results at the same time (Hennessy & Murphy, 1999). According to Mercer and Littleton (2007), task design and close relationships are necessary preconditions for a successful collaboration. Tasks should be open-ended, challenging enough, and allow students to work together (Mercer & Littleton, 2007). For example, elementary students (ten-to-twelve-years-old) managed to engage in and learn creative knowledge-creation by collaborative designing with appropriate support (Kangas et al., 2013). Rowell (2002) examined one pair of young students' interactions during a designing and making task, where the focus was on analysing the nature of participation through the words and actions between a student pair. Rowell found language skills to be crucial in collaborative problem solving. However, there is little research available on young children's collaboration in design learning concerning creative material activities (Vass & Littleton, 2009). Fredriksen (2011a; 2011b) investigated three-to-five-year-old children's interplay with three-dimensional materials (like clay) and the study focused on the interactions between the children and materials. Fredriksen identified four different processes, particularly the intersubjective process of expressing, sharing and negotiating meaning through social interactions. Yliverronen and Seitamaa-Hakkarainen (2016) observed that five-to-six-year-old pre-schoolers worked logically together in a situation where they decorated fabric bags, and the skill learning phases of perceiving, making and interpretation were revealed from their learning. Yalkin (2015) created a model for design education in kindergarten, which aimed to develop young children's thinking skills in a creative environment.

To conclude, young children must accomplish several cognitive skills for a successful collaboration. Firstly, they must be able to share and express their own ideas. Secondly, collaborative learning requires communication either verbally or non-verbally (gestures, facial expressions). Thirdly, planning their own activities during the collaborative situation is very demanding because they have limited experience in collaborative activities outside of free play. Essential is, that preschool education offers opportunities for children to exercise collaboration, listening to others and acquire knowledge in interaction with other children, kindergarten staff and the immediate environment (FNBE, 2016, 18). From a perspective of design education, it is important to hear children's voice inside of the designing process and understand children's way to generate ideas further.

Data collection and methods of data analysis

The present case study took place in a public preschool situated in a small Finnish village. A total of 15 six-year-old pre-schoolers, seven girls and eight boys, took part in the craft project, which was implemented in the middle of the preschool year. Generally, the group worked with a kindergarten teacher and an assistant, but during the data collection, one of the authors and an external assistant were also guiding the craft activities. The preschool group was divided randomly into four groups of three or four children during the designing task. After a short motivation session that consisted of an animal fairy tale and a song, the teams were asked to decide which animals they would like to be. The team names Big Squirrels, Small Squirrels, Birds and Foxes were decided on together within the teams. All the groups built up their own places (shelters) using tables and blankets for the designing session. The first task was to discuss ideas related to the themes, such as how animals live in nature, and which items could make nests comfortable for them. As an outcome of these discussions, children were asked to design convenient homes for forest animals and simultaneously draw their thoughts on a sheet of paper from a bird's-eye view. The adult's role was mainly to scaffold the children's mutual work without giving ready answers and to take care of video recording. Children were encouraged to investigate and explore materials that were available for the designing task: textile materials, package materials and materials from the forest (such as sticks, pine cones, spruce branches).

The data collection consisted of five working sessions, about 1.5 hours at a time (see Table 1). In total, the data are comprised of video recordings from each group's designing and construction sessions (about 75 minutes per group per session), presentations of the ready-made nests (39 minutes), 127 digital photos of the ready-made products, and each group's sketched plans. Since the present study focuses on preschoolers' collaboration during a craft product designing, only the first session, which included all the designing activities (74 minutes of video data in total), has been analysed. All groups' designing activities started at the same time, but the intensity of how they concentrated on the task varied. The time groups used in the first session varied from 14 to 25 minutes. Table 1 shows all craft project sessions, the main content of the session and the time used in each session.

Table 1: Activities of the whole craft project and duration of video data.

Session	Content	Video data			
		Birds	Foxes	Big Squirrels	Small Squirrels
1st	motivation , brainstorming, **designing**	**20:00**	**15:00**	**14:00**	**25:00**
		Total 74:00 minutes designing			
2nd two days later	presenting ideas for each other, construction	2:00	4:00	7:00	6:00
		First total 19:00 minutes idea presentations, then total ca. 55 minutes construction from each group			
3rd five days later	constructio n	Total ca. 75 minutes from each group			
4th one week later	construction, modelling clay animals	Total ca. 75 minutes from each group			
5th after one week	finishing and presenting ready-made nests	10:00	8:00	9:00	12:00
		Total 39:00 minutes presentations			

The data analysis focuses on each group's video recorded designing session, which is the main data in this study. We adapted Ash's (2007) methodology of micro-level analysis for tracking children's collaboration and meaning making in designing. The video data were segmented and transcribed first (Derry et al., 2010). We transcribed only the actual collaborative designing from each session, not the activities before designing. Each group's transcribed data were written into a table format that consisted of two sectors: what was said and what was done (Sawyer, 2006b, p. 195). The units of analysis were a statement (meaning of the content) and related actions (see Table 2). Since young children often use a lot of embodied expressions to replace missing words (Yliverronen & Seitamaa-Hakkarainen, 2016), we also focused our observation on the gestures together with the children's talking. Thus, in the verbalised data we labelled the turn-taking, i.e., the speaker, and the actor (drawing, pointing). Table 2 presents an example of the organisation of the video data: the left side presents the children's discussion (and turn-taking, when the speaker changes) and the right side describes what was happening (observation of gestures and actions).

Table 2: An example of transcription and observation from the group Big Squirrels.

Min	What was said A=Ada, E=Emma, L=Luke, J=Jason	What was done
	12. A: Someone could make blankets there.	13. Draws
2:00	13. E: I’m gonna make blankets! Let me do it.	14. Points with a pen 15. Draws
	14. A: And then here.	
	15. E: Yeah, yeah. Jason, legs to the bed, so it stays up kinda like a chair.	16. Draws the shape of the legs in the air with his hands
	16. L: Like this.	17. Draws
	17. A: Kinda chair.	18. Points at the table leg with her hand
	18. A: Like…have a look at this.	19. Encourages Jason
	19. E: So… now you’re making….	20. Jason starts to draw
		21. Draws and shows with a pen. The others
3:00	21. A: Everyone can make their own’s here.	also draw simultaneously. 22. Looks at the plan 23. Draws
	22. A: Emma can make it better.	
	23. E: I’m gonna make that a little bit longer.	25. Asks with a look. Ada nods. Starts to draw.
	24. A: Then a carpet. And a lamp!	
	25. E: Okay. Who starts? Me? Okay.	28. Shows with her hand. Looks towards Luke.
	26. L: Okay.	
	27. A: Let Jason…	
	28. E: This is the leg of the lamp. Will you make this so, that the lamp gets a round form…?	30. Looks towards Emma
	29. A: I’m gonna do…Luke can do it.	
	30. A: Where do I put this?	

The qualitative content analysis for data analysis was inspired by Määttä, Järvenoja and Järvelä’s (2012) as well as Kumpulainen and Mutanen’s (1999) studies, where both analysed students’ interactions in collaborative learning. Määttä et al. (2012) conducted a micro-level analysis of the quality of interaction in a small group, particularly the quality during the on-task episodes. Kumpulainen and Mutanen (1999) provided useful content categories to analyse young students’ verbal interactions where students negotiated and built their own understanding about the given task. Based on those categories, we adapted and developed our qualitative content analysis categories that capture the dimensions of peer verbal and embodied interaction (see Table 3, below). From the group's video recorded design sessions, we analysed each participant's spoken statements (*f*=357). After identifying *the speaker*, we classified *the main focus of discourse* (each statement/activity) in order to better understand the content and the proceeding of each group's collaboration. We identified whether the statement of the *verbal collaboration* represented 1) ideation (proposing a design idea such as shapes and materials), 2) developing (reacting to the presented idea or questioning the design), 3) agreement or disagreement (liking or disliking the presented idea), 4) questioning (presenting specified questions or ideas in a question form) and 5) organising process (asking someone to do something such as drawing or dividing turns). This data-driven classification corresponds to other studies of design such as Kangas et al. (2013), Lahti, Seitamaa-Hakkarainen, Kangas, Härkki and Hakkarainen (2016) and Welch, Barlex and Lim (2000). The *embodied collaboration* focused on 1) drawing, 2) working with materials (investigating and picking up materials to support designing), 3) non-verbal cooperation (supporting ideation with hand gestures, nodding or shaking head or active monitoring of the ongoing situation) and 4) playing and off-topic activities (singing a song that is related to the theme, taking on the role of an animal related to the presented story or off-topic activities, which were not related to the task).

Table 3: Classification schema.

Main categories	**Subcategories**	**Description**
Verbal collaboration	Ideation	Students generate ideas, beginning new designing cycles
	Developing	Developing the design idea further or commenting on or answering a presented question about designing
	Agreement/ Disagreement	Supporting one's design idea, or disagreeing
	Questioning	A question, which generates or defines designing
	Organising process	Talk that focuses on organising one's work, planning and division of work (whose turn it will be)
Embodied collaboration	Drawing	Drawing on the paper or picking up materials, touching the perceived object
	Working with materials	Investigating materials, picking up materials or tools for implementation
	Non-verbal attendance	Monitoring silently what others are doing, supporting verbal ideation with gestures
	Playing and off-task	Playing a role, which is evolving from the task's theme or activity, which is not related to the task

After visualisation of the groups' statements and embodied collaboration (Figures 2–5), we identified children's social roles in their peer groups. This classification was based on children's verbal activity and the content of their statements. Embodied collaboration, especially non-verbal attendance, also gave information about a child's role in the group and confirmed classification. We found four different kinds of social roles, which we named leaders, partners, followers and observers. These roles are described in the end of results chapter.

The reliability of the analysis was ensured by using a parallel coder. After the first independent coding round, an inter-coder agreement was 79.5%. Both coders realised that some extra categories were needed to be able to represent children's speech and designing activities with enough detail. Coders negotiated and constituted a joint understanding of the required classification, and after this phase coders individually coded the data again. After the second coding round, the inter-coder agreement was 90.7%, which indicates significant reliability of the classification.

Results

Overview of groups' designing activities

The data were first classified on the children's verbal interaction and embodied design activities. The histogram below (Figure 1) presents verbal collaboration (light grey on the left, numbers 1–5) and non-verbal, embodied collaboration (dark grey on the right, numbers 6–10). It represents (from left to right) each preschool groups' interaction (Birds, Foxes, Big Squirrels and Small Squirrels) related to designing. Next, it presents embodied interaction in the same order. The children's verbal collaboration was clearly focused on designing, they proposed ideas, developed ideas further, they were agreeing and disagreeing with the proposed solutions and they were asking questions and organising their processes. The embodied interaction was focused on drawing, investigating materials, non-verbal participation like hand gestures, as well as playing around or other off-task activities. Generally, the children were mainly concentrated on their work, but naturally there were differences in their concentration.

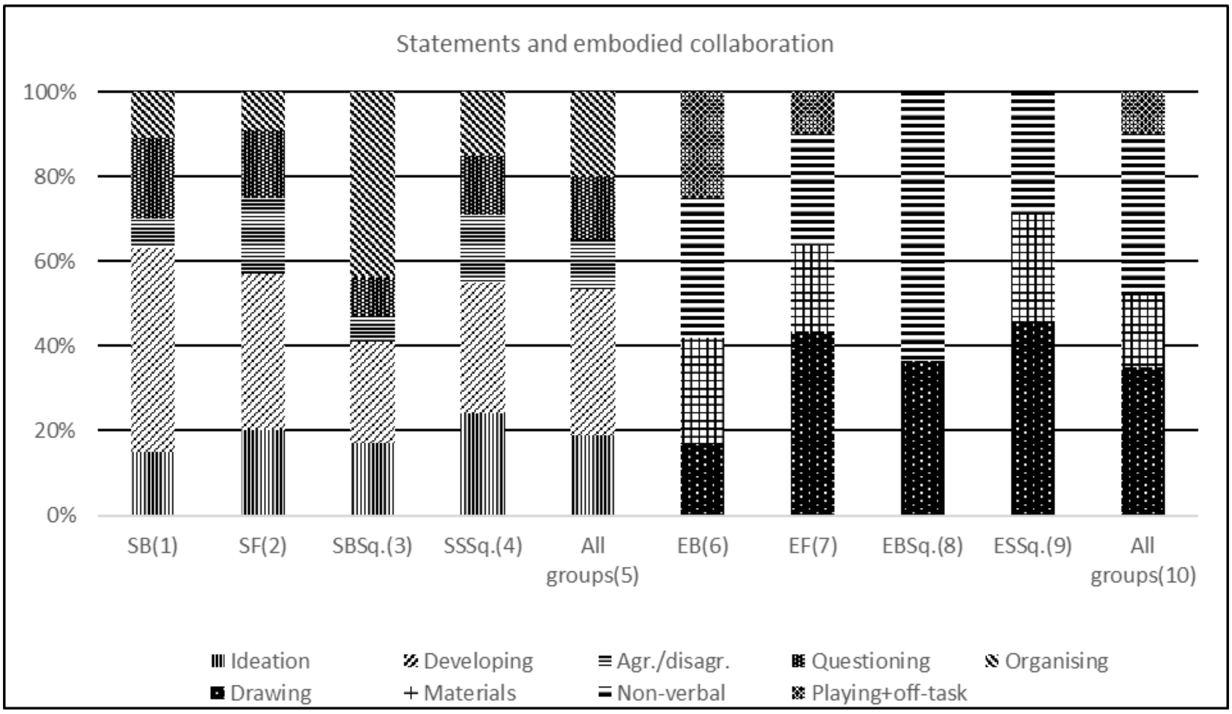

Figure 1. SB=Birds' statements, SF=Foxes' statements, SBSq=Big Squirrels' statements, SSSq=Small Squirrels' statements, EB=Birds' embodiment, EF=Foxes' embodiment, EBSq=Big Squirrels' embodiment, ESSq= Small Squirrels' embodiment.

The verbal interaction (columns 1–5) appeared to be quite similar in all teams. One third (1/3) of all groups' statements dealt with designing the idea further. On average, one fifth (1/5) of all verbal statements offered ideas for the given task and began new designing cycles. Three groups of four had few statements that focused on organising one's work or whose turn it was. Only the group Big Squirrels had more organisation for taking turns with drawing or presenting ideas. The pre-schoolers had only a few expressions of straight agreement or disagreement (yes or no). They generally focused on the presented idea and continued their discussion from the basis of it.

However, when comparing groups' embodied collaboration and off-task activities (columns 6–10), there appears to be more variation between the groups. The Foxes concentrated on drawing, whereas the Birds had more off-task activities and non-verbal gesturing. This non-verbal gesturing was related to the designing, including silent monitoring of working (what the other group members were doing) or more versatile gesturing like pointing or proposing ideas with gestures to support their statements. The Big Squirrels' embodied collaboration consisted of drawing and non-verbal activities (such as using hands or head for gesturing and active, silent monitoring and attendance). The Small Squirrels' designing session consisted of drawing, material investigations and constant non-verbal attendance. Three groups of four investigated the materials, and only the Big Squirrels did not use that possibility. Playing, like taking on the role of a baby animal, and other off-topic-activities were present only in the Birds and Foxes groups, but did not occur at all in the Big Squirrels' or Small Squirrels' designing sessions.

In the following, we will describe each team's designing process on a more detailed level and introduce children's social roles, which were found in their peer collaboration.

Groups' peer collaboration on the task

Group Birds

Three children, one girl and two boys, belonged to the group Birds as seen in Figure 2. The division of the participation in relation to designing varied between children: Max was active in proposing ideas (ideation) whereas Mandy actively continued to develop ideas and elaborated on these ideas. However, most of the group's verbal statements were from Mandy, who presented about half of all the statements. It was typical for Mandy and Max to propose and develop the design ideas in a question form. Mandy also took on the role of organising their process. Elias was this group's silent observer. Although he did not participate actively in the verbal interaction or propose any questions to generate designing, he suggested some ideas and elaborated on them by using hand gestures. Example 1 represents his way of proposing suggestions.

Example 1

Max: Yeah. Let's make a pinecone storage.

Mandy: Yeah. Where do we make it?

Elias: [patting his hand above the drawing paper to show his suggestion for the place]

Mandy: Let's not make it next to these, cause then it's kinda stupid if the storage…

Elias: [patting another corner of the paper]

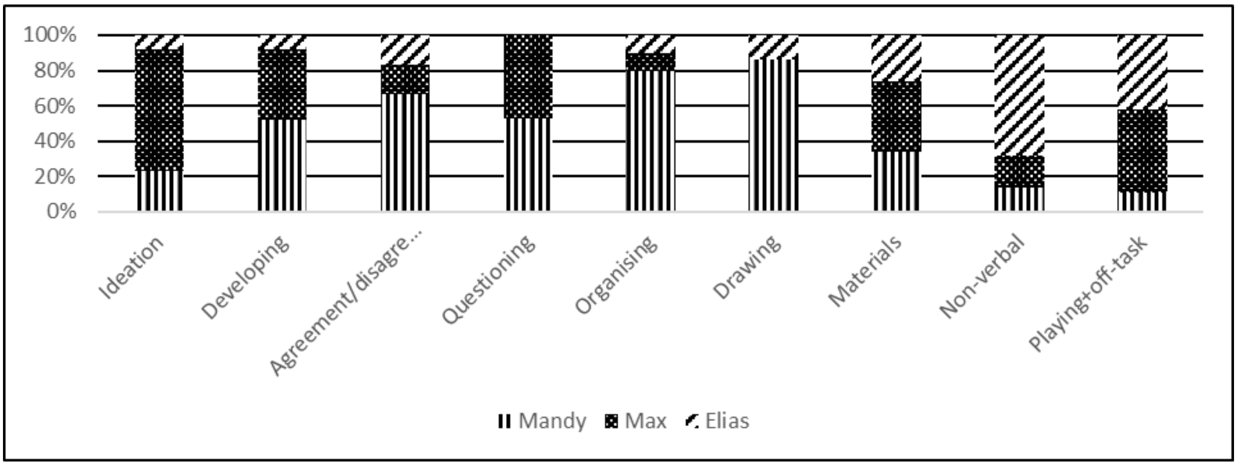

Figure 2. Group Birds' statements and embodied designing activities.

Mandy and Max focused on drawing. While Mandy dominated the drawing activities, Max and Elias engaged in playing activities at the same time. Although Max engaged in quite a lot of playing activities during the designing session, he was also the most active member of the group when considering their generation of ideas. He seemed to play and have his playing role, but at the same time he monitored group members' conversation and participated in it actively. This is very typical for preschool-aged children: they can move smoothly between real-life roles and fantasy roles (see review e.g., as suggested by Vygotsky, (2004)). As noted earlier, Elias contributed a minimal number of statements, but he actively monitored other group members' actions and made non-verbal suggestions for the designing task by using gestures. In general, all the group members mostly investigated the materials together.

Group Foxes

Two girls and two boys formed the group Foxes as can be seen in Figure 3. Rose and Axel were more active verbally, but the two other children, Sandra and Hugo, also had their roles in the discussions. Axel was the most active in proposing ideas, but the other two children, Rose and Sandra, equally participated by building up on those ideas and developing them further. The Foxes chatted mostly between two children, but there was less discussion as a group.

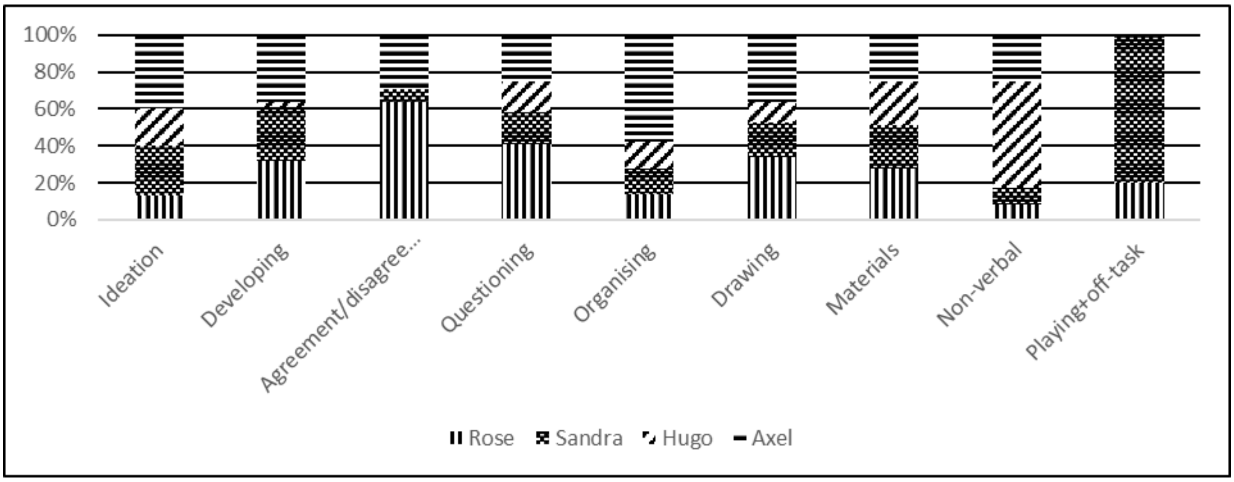

Figure 3. **Group Foxes' statements and designing activities.**

Rose showed good teamwork skills during the designing session. She, for example, gathered coloured pencils for the whole group and encouraged Sandra to continue with the designing task when she tried to end working. Rose also gave positive reactions for the other group members' suggestions and showed her agreement. It was typical for Rose to propose questions, but this is because of her tendency to present her ideas in question form rather than give straight suggestions. The Foxes only had a few statements for organising their work, and Axel presented most of these.

Figure 3 shows clearly each child's role in the embodied designing activities. Rose and Axel carried out most of the drawing activities, whereas Sandra managed to concentrate on the task only at the beginning of the designing session. She rather played most of the time under a table. Rose was mostly employed with the given task and chatted about their drawings with Hugo and Axel. These three children, (while Sandra was playing alone) explained their drawings at the same time when they were implementing them. Hugo took long pauses from drawing, but he used those moments for active, non-verbal investigating of other children's statements or drawings. The following example illustrates the Foxes' collaboration while they were drawing. Each of the group members seemed to work independently, but they actively monitored what the others were doing.

Example 2

Rose: Sandra, come here. There's colours here. Hey, where do we colour? [she has taken coloured pencils, chooses colours and begins colouring]

Hugo: Hey, I'm gonna put a steering wheel and wheels on my bed! [draws]

Axel: I'm gonna make…I don't know [continues drawing]

Hugo: I'm gonna make a wheel bed. Are you gonna make a putt-putt tractor? [continues drawing]

Axel: Heh, and then there's also that… [draws and chatters alone]

Hugo: Did you draw wrong? [asks Axel and draws]

Axel: Yeah [collects more coloured pencils]

Group Big Squirrels

Girls, Ada and Emma, and boys, Luke and Jason, were members of the Big Squirrels as seen in Figure 4. This group's verbal interaction was slightly different than the other groups' discourse. From Figure 4 (below), it can be seen that Jason did not participate in the verbal interaction during the designing session at all, and most of the discussion was between the girls.

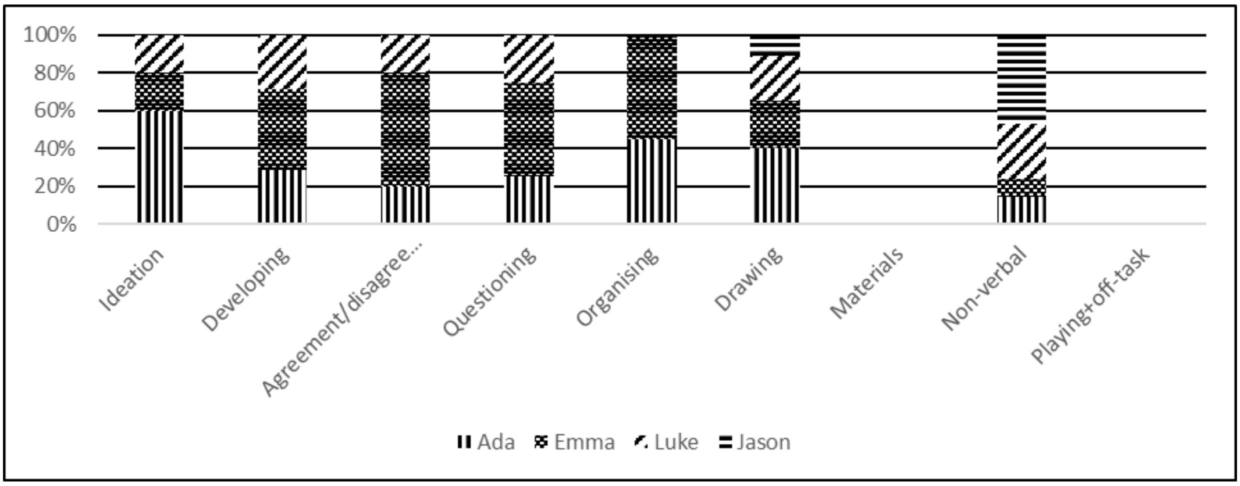

***Figure 4.* Group Big Squirrels' statements and embodied collaboration.**

Most of the verbal statements focused on organising the group's work to give equal possibilities for each member to propose and draw their ideas for the design. For instance, Ada and Emma tried to engage Jason by giving him a pencil and advising how to draw the bed's leg (see Table 2: An example of transcription and observation from the group Big Squirrels). The group conversation mostly proceeded in this way, where Ada gave a suggestion, Emma replied, and Luke monitored the girls' discourse, and then he gave his input to the discussion. The group's cooperation started out well, but after an adult's verbal intervention they felt hurried, and the designing session became scattered.

Group Big Squirrels' embodied collaboration consisted mainly of drawing, and as stated before, they shared the turns for drawing and proposals. Ada drew a little bit more than the others, but Emma gave her drawing turns to Jason. The group's assistant (the kindergarten teacher) encouraged the children to investigate materials for the designing task, but they decided to continue drawing and discussing. This group's boys were deliberate, active observers: they monitored the situation silently, while the girls used more gestures to specify their statements. Group Big Squirrels did not have any play or off-topic activities during the designing task.

Group Small Squirrels

Like the other groups, the Small Squirrels' group consisted of two girls and two boys as can be seen in Figure 5. Laura participated slightly more than the others. She was verbally active, and she initiated most of the ideas or developed them further. She also drew quite a lot, and the others let her keep that role, whereas Tim willingly examined the materials. Seeing and touching natural materials from a forest clearly helped him to generate ideas. Paul often used a question form in his speech. For instance, he wanted to ensure that he had understood things correctly, but he also gave some suggestions for the design and defined the idea in a question form. Melissa presented good teamwork skills: she carefully monitored what the others said, but she also gave many suggestions to generate the Small Squirrels' plan.

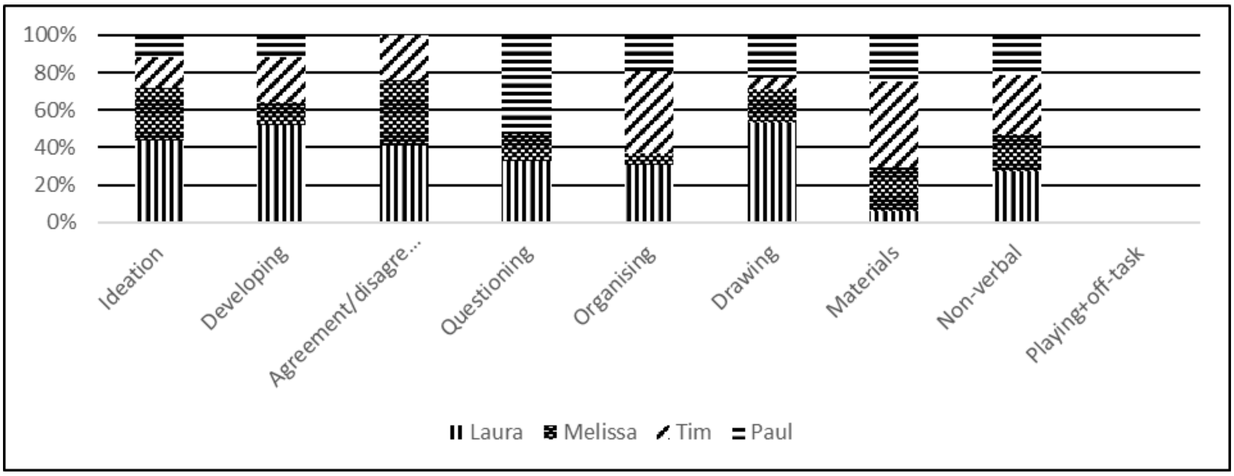

***Figure 5.* Group Small Squirrels' statements and embodied collaboration.**

Tim played a notable role in encouraging the other group members to draw their ideas on the paper. This was because of an active organising of the group's cooperation. The Small Squirrels did not have any play or off-topic activities during the designing session. Example 3 illustrates the group's discourse, where all group members participated.

Example 3

Teacher: What else could be there?

Laura: Well, something soft, well…

Tim: Hey, cushions. Here and here [pointing with her finger]

Laura: I got it. Can there be spruce branches?

Teacher: Yes, spruce branches. Would they be like seats then?

Melissa: Or like as a carpet? Where should they be then? [pointing with her hand]

Tim: There [pointing with his hand]

Laura: No, here in the middle… [pointing to the designed door with her hand]

Paul: Could it be there too? [pointing with his hand]

Tim: Yeah, like a…

Laura: No, but there's an entrance

Melissa: There can be a lobby, where the squirrels can wipe their feet [pointing with her hand, drawing]

Laura: Okay. To the lobby, and here in the middle of the floor [pointing with her hand]

Tim: We're gonna make… so the carpet's there in the right spots

Children's roles in their peer groups

Four types of roles, both leader and follower roles, were found in children's peer collaboration. Each group had a *leader*, an active child who was active both in verbal and embodied collaboration. Leaders acted with *partners*, and these children generated most of the groups' discourse together. Partners had an active role too, but they preferred to answer the presented ideas by developing them or by presenting developmental questions. *Followers* were active actors, but they preferred to investigate the situation first and presented less statements as leaders and partners. *Observers* were the most silent children in their groups. Their role can be perceived from the subcategory of non-verbal embodied collaboration. Observers did not say anything or contributed a significantly lower amount of statements than the other group members during the designing session. They monitored the situation silently and gave some suggestions for the task using gestures.

Conclusion

The main objective of this study was to investigate the nature of preschool-aged children's collaboration during a designing task from the perspective of verbal and embodied interaction. This was analysed within the frame of sociocultural learning from children's discussions and embodied design activities with their peers in a situation where they received a task to design forest animals' nests. Speech, drawing and investigating materials, as well as silent monitoring and gestures, like hand movements or facial expressions and eye contact, were the basis for the children's communication and cooperation. The aim of the intervention in the kindergarten was to act in the most child-centred (Lerkkanen et al., 2016) way, where after a motivation session, the children received the task to solve and instructions to work in the groups with their peers. Although the designing problem was not defined by the children, it was designed to align with their interests and be demanding enough for them. The children had to imagine the result of the task without making the final product at the same time (Hope, 2008), and they also had to verbalise their thoughts to the other group members, as well as find a way to work together as a team. The concept to work collaboratively, to solve the given task with peers and receive only minimal help from the adults, was new for these children. To support their activities, the children were given concrete materials to help their designing (Hope, 2008), and they were encouraged to investigate them. The possibility to investigate different kinds of constructing materials helped the children create more details for the plans, but there were, however, differences between the groups in how much their ideas arose from the materials or from discourse. Real materials from a forest and the texture of the materials, like softness, were important inspirational sources of ideation, which provided energy for the designing and pushed the processes ahead.

The results of the intervention showed that preschool-aged children succeeded in working collaboratively and finding ways to solve the designing task verbally with their peers. They had enough skills to express their thoughts, consider and listen to the other group members and find a way to collaborate as a group. Preschoolers' discussions followed a convenient designing session's structure, although their discourse consisted of shorter statements and less words than older children's or adults' conversations (Kangas et al., 2013; Lahti et al., 2016). Young children's verbal expression is often comprised of only a few words, and they usually don't generate proposed ideas by pondering various alternatives. Because of this, the designing cycles from an idea to another suggestion were quite short in the present data. Ideas were followed by some developmental statements or defining questions, and suggestions were easily accepted without disagreements. By using a lot of statements for organising their process, group members tried to give equal possibilities for all to express their ideas, like the Big Squirrels did. It was clearly seen that a child's ability to use language determined his or her role in the groups' collaboration (Fawcett & Garton, 2005). A shared understanding does not always need words, but communication can also be based on embodied thinking. There were differences between children in how much they used non-verbal expressions with gestures. For some children, versatile expression using both speech and gestures was natural, but other children were too shy to tell their thoughts aloud, although they made good suggestions for details using gestures. Typical non-verbal expressions were nodding or shaking the head, pointing or tapping the sketch with the hand or a pencil, or delineating the suggestion, such as when Emma clarified the form of a lamp with her hands. As is well known, play is an essential part of a pre-schooler's life, and therefore it is impossible to separate it from young children's collaborative activities. The young children clearly needed time to process the given task by doing something else for a while. In this case, some of the children lolled in their shelters under the tables, some other children played for a while, like Max and Sandra, but after a short break, they concentrated on the task again. Especially for Max, who took the role of baby bird, play seemed to be an expression of embodied thinking.

Design discourse has the unique potential to support shared thinking processes and gives a natural context in which to learn collaboration (Murphy & Hennessy, 2001). Opportunities for collaboration in crafts should begin at the preschool level, because craft activities provide a natural real-life situation to cooperate, negotiate and finally create a common product with peers. Thus, it is extremely important to trust in children's abilities to solve the given task in their own way without giving too much scaffolding (Sawyer, 2006a). An appropriate amount of scaffolding from a more skilled person assists children by passing on their skills, but children's own implementation of collaboration is the most valuable and instructive experience for them.

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23.2

Design from Discard: A method to reduce uncertainty in upcycling practice

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Abstract

Upcycling is a suitable option for municipal solid waste recovery, especially, in the unorganized waste management scenario(s), where conventional waste recovery options are not efficient. Unlike standardized industrial manufacturing, upcycling is highly dependent on the quantity and quality of discards, and the involved stakeholders. Novel designs are required to suit varying considerations of every new upcycling set-up, and practitioners face uncertainty to parallel handle the variety and develop a design solution. A very few available design education based methods involve and guide design practitioners to handle the challenges in their case-based upcycling practice. However, these research studies are the first attempts to practice upcycling in an academic environment, and the results were limited to concepts and prototypes. This work categorically identifies the vital requirements regarding discard and stakeholders, discuss the theoretical foundation to handle the variety, and develop a practice-based design education method for upcycling practice. We propose a method - Design from Discard, to facilitate the participants to study the characteristics of discards, conceptualize a design as per the identified stakeholder(s), and accordingly develop upcycled designs. The method is explaining with an illustrative case where the design practitioner(s) conceive a new design from contextually discarded metalized film packaging. Finally, findings and research directions are addressed to bring new insights to the effective application of the proposed method as per diverse upcycling requirements.

Key words

upcycling packaging waste, practice-based design method, design from discards

Introduction

Upcycling is an activity that utilises the limited affordance of the *discarded* products to develop a new product (or material) of comparatively better value (McDonough & Braungart, 2013). Upcycling activities have proved to be effective in delaying waste disposal (Singh & Ordoñez, 2016), eliminating the need for new products, enhancing the aesthetic value (Sung & Cooper, 2015; Wilson, 2016), and consuming less energy in material circulation as compared to recycling (Nilakantan & Nutt, 2015). Particularly, in the case of developing and underdeveloped countries, upcycling is a suitable option to *discard* recovery (Slotegraaf, 2012), where the other waste management techniques, such as recycling, biodegradation, landfilling, incineration, etc., are not efficient irrespective of latest technological interventions due to system and service level limitations (Guerrero, Maas, & Hogland, 2012; Hoornweg & Bhada-Tata, 2012).

At the individual level, renowned designers, ordinary individuals, and even marginalised communities with limited knowledge have developed upcycled products (Radjou, Prabhu, & Ahuja, 2012; Sung, Cooper, & Kettley, 2014), creating interest and trends towards upcycling. Along with organisations like TerraCycle in the United States (Li, 2014), organizations like 'Spiral foundation' in Nepal (Spiral Foundation, 2016), 'Taller Re_crear' in Chile (Re_crear, 2016), 'Waste for Life' in Argentina (Baillie & Feinblatt, 2010), and many other initiatives (Hira, 2017), provide substantial evidence on unique models to support *discard* recovery through upcycling. Despite the scope and participation of individual and organizational design interventions, upcycling interventions struggle to handle the contextual challenges in upcycling (Han et al., 2017; Sung, 2015).

Unlike the industrial design process, where standardisation leads to mass production, upcycling is a highly customised activity. Every new upcycled design is highly dependent on the regional waste management sites to consistently supply the unattended *discard*s, to the upcycling setup (Ali, Khairuddin, & Abidin, 2013; Richardson, 2011). Moreover, industrial manufacturing processes cannot be applied to shape and form discarded materials to mass manufacture upcycled goods, and case-specific techniques are developed for each upcycling case (Baillie, Matovic, Thamae, & Vaja, 2011; Han et al., 2017). Other issues such as concerns of the workforce for customised manufacturing (Dissanayake & Sinha, 2015) and applicable regulations for the use of *discarded* materials (Ordoñez & Rahe, 2013) lead to multifaceted considerations for distinct upcycling cases. Collectively, these issues limit novel design interventions in upcycling, irrespective of opportunities present in a sector.

On the other hand, design education institutes have recently attempted to handle the multifaceted considerations in upcycling-based cases. Very little research literature is available which demonstrates design research support to handle the contextual challenges in upcycling. Design institutes and universities are engaging design practitioners by means of projects to handle the barriers in creative problem-solving. 'Waste for life' (WFL) (wasteforlife.org) is such a collaborative organization of academic practitioners and ground cooperative partners, which have developed a standard technique and machine to manufacture waste-based composite 'material board' that aids local waste recovery (Baillie & Feinblatt, 2010; Baillie, Matovic, Thamae, & Vaja, 2011). However, an adaptation of the standard practice, such as WFL, is focused on the specific regional opportunities and constraints, and may not be suitable for requirements of varying upcycling initiatives. There is a need for design research support for varying upcycling opportunities and practice that provides novel solutions appropriate for individual contextual settings.

Interestingly, a few of the design institutes have practiced design education as an effective way to incorporate professional knowledge in upcycling-based activities, thereby enhancing creativity and creating variety in upcycling. In the few available methods developed by researchers, design practitioners are guided to generate suitable ideas for upcycling. 'From Industrial Waste to Product Design' (W2D) is such a collaborative work of recycling firms, engineering consultancy organisations, along with design researchers in Sweden. Researchers collaborate with recycling industries of highly organised waste management scenarios to collect their non-recyclable waste, and then designers use the *industrial discard*s for upcycling practice (Ordonez, Rexfelt, & Rahe, 2014; Ordoñez, Rexfelt, & Rahe, 2012). Another significant contribution is the 'Design from Waste' (DfW) method developed by researchers for unorganised waste management scenarios in India (Khan & Tandon, 2016). They identified that in their case most of the 'recyclables', in the absence of system level support, end-up in landfills. In their course-based upcycling practice, the practitioners were guided to identify recyclable and unrecyclable *discard*s at municipal waste disposal sites and utilise the limited affordance of *discard*ed materials to conceptualise upcycled products.

The two methods presented here provide a knowledge base for upcycling practice that was much needed to resolve the issues faced by an individual as well as organisational upcycling activities. W2D and DfW are the only methods available that can be 'tested' to varying upcycling opportunities and practice. Further, in a comparative work, both the methods, i.e., W2D and DfW, were compared on their contextual set-up, education set-up, the framework(s) presented to practitioners, and the results obtained (Ordoñez, Khan, Tandon, & Rexfelt, 2016). Some of the valuable insights and research directions of the work include:

1. Planning the product segment according to the prior experience of design practitioners could increase creative problem solving,
2. The duration given to the practitioners for completing the project should be estimated and planned according to their design proficiency,
3. If the practitioners are students of design education, then their learnings should be followed and the upcycling process should be accordingly developed.

The comparative work also concluded that the characteristics of contextual *discard*s and stakeholders are the governing factors to devise a better practice-based education method to *discard* upcycling.

The following are the significant research gaps that have still to be resolved to lead to better-upcycled products:

1. The existing methods agree on the point that 'discontinuity' in *discard*s is an integral characteristic, and varying quality of *discard* substantially affects the current upcycling based pedagogy and limits the scope to concepts and prototypes. Moreover, there is a need for clear understanding on how the *discard*s should be handled to result in an upcycled product.
2. The methods had to deal with multiple considerations, e.g., varying quality of *discard* provided by a recycling firm (as in W2D), incorporating marginalised communities for hand-made manufacture (as in DfW) etc., to overcome the limitations in upcycling identified in the individual case.

These two teaching-learning pedagogies are the first practice-based approach to show 'how' upcycling can be benefited from the academic practice. However, the current methods merely considered the stakeholder as an important factor and lack the details on including the requirements of identified stakeholders, e.g., recycling firms, marginalised communities, etc. in their methods. To enhance the quality of outcome, a detailed model of 'what' are the multifaceted requirements and 'how' to create the final upcycled design according to the identified needs, is essential.

In continuation, one of the fact market, is a must for the acceptability of product in the competitive market (Wang & Hazen, 2016). Moreover, design adaptation with reference to changing user requirements is expected and is vital in every design process, i.e., the customer requirements, still has to be explored and implemented in an upcycling process. User expectations, customer influences, etc., regarding an identified m any product for succeeding in market competition. In other words, radically different design responses are required from the design researchers to address the interwoven issues, rather than manipulating the existing methods (Dorst, 2011; Sandberg & Aarikka-Stenroos, 2014).

Accordingly, this article presents a design education-based upcycling method—Design from *Discard* (DfD)—that guides and trains the design practitioners to create contextually suitable upcycled products. In the subsequent sections, we first explain the theoretical foundation behind the DfD method, on how the identified research gaps regarding *discard*, manufacturer, and customer, could be resolved by the DfD method. Further, in the method section, the suggested steps of DfD method is elaborated with one of the illustrative case(s). Here, a locally unrecovered *discard*, 'multi-layered flexible film,' is identified and for a selected region, design practitioners survey relevant sites and stakeholder(s), collect the necessary information, explore the upcycling possibilities, ideate and correlate the design features, and deliver a suitable upcycled product. The manuscript also discusses a unique 'correlation wheel' within the DfD method that associate the identified multifaceted requirements together to create an appropriate design. Finally, we discuss the issues related to the conducted steps, the scope of actual application, and further research directions of the DfD method regarding diverse upcycling opportunities.

Theoretical Foundation

It is expected that the DfD method should be efficient to handle the variety of *discard*; and also include various *stakeholders*, i.e., design practitioners, manufacturers, customers, etc. The method should also be capable to understand the personal interests of stakeholders, in the process as well as the outcome. This section proposes the foundation of the existing theories and developed practices, based on the factors that are related to effective participation of designers, exploration of *discard* affordance, and stakeholders' interests, to devise an approach to resolve the identified issues.

Effective Involvement of Participants

Project-based learning is often preferred in an academic environment when practitioners are exposed to actual scenarios and learn from real-world problems (Boss & Krauss, 2014). In the presented literature of DfW and W2D methods, it has been found that the quality of upcycling concepts was highly influenced by the contribution of participant practitioners. However, these approaches did not consider the significant details of engaged participants. It is recommended that such project-based education pedagogies have to be designed by critically considering the strengths and weakness of the individuals to ensure effective participation (Brandt et al., 2013;, Yu, & Chen, 2011; Scheer, Noweski, & Meinel, 2012). In this work, we have selected Master of Design scholars of our institute as the participants. During the initial planning of the coursework, the past education of the participant designers and their professional experience were recorded. Besides, as the practitioners were in the third semester of their two-year master's program, the common coursework in their previous two semesters has also been considered as the recent learnings and knowledge may also influence the practice on the method. This was also taken into account during group formation.

Figure 1 presents the exercise of group formation for the 18 design practitioners enrolled for the task. The group formation was carried out in such a way that individual characteristics such as education, and experience complement each other. The educational backgrounds of practitioners were limited to undergraduate courses in the domains of Mechanical, Electronics, Civil and Computer Engineering as well as Industrial and Product Design. A total of 5 groups were formed to equally balance the strength of each group (Mcmahon & Bhamra, 2016), with three to four members with an engineering background, and one member being exposed to design education.

The scope of growth of participatory design interventions in waste management sector is increasing (Cucuzzella, 2016; Pavlova, 2013), however the existing examples (Lange, Hughes, Rahbar, Matzen & Caldron, 2012; Heidenspass, 2016; Janwani, 2016; Szaky, 2014) are stand-alone practices that involve risk, lack research support, and are therefore difficult to adopt for a larger segment of 'traditionally practising' design practitioners. As an attempt to effectively involve the participants in an unfamiliar sector, the initial stages of DfD method have been designed to first make the practitioners aware about the popular issues, provide visibility to the opportunities available for individual growth and, then motivate them to work on the upcycling process (Wormald, 2011).

GROUP 1	G1, Member 1 (G1M1)	G1M2*	G1M3	G1M4	Education + Experience
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electronics and Communication Engineering	Industrial and Product Design	Computer Science Engineering	Mechanical + Electronics + Product + Computers
Industry Experience	Faculty Advisor (1 y*)	nil	Product Designer (7 m*)	nil	1 y 7m
GROUP 2	G2M1	G2M2	G2M3	G2M4	
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electronics Engineering	Computer Science Engineering	Civil Engineering	Mechanical + Electronics + Computers + Civil
Industry Experience	nil	Freelance Graphic designer (1 y 2 m)	Freelance Designer (7 m)	nil	1 y 9 m
GROUP 3	G3M1	G3M2	G3M3		
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electronics and Communication Engineering,	Leather Design		Mechanical + Electronics + Leather
Industry Experience	Graphic Designer (1 y)	Programmer Analyst (10 m)	Product Designer (1 y)		2 y 10 m
GROUP 4	G4M1	G4M2	G4M3	G4M4	
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electrical and Electronics Engineering	Textile Design	Civil Engineering	Mechanical + Electronics + Textile + Civil
Industry Experience	Nil	Software Engineer (1 y 8 m)	nil	nil	1 y 8 m
GROUP 5	G5M1	G5M2	G5M3		
Educational Background (Bachelor's Degree)	Mechanical and Automation Engineering	Computer Software Engineering	Accessory Design		Mechanical + Computers + Accessory
Industry Experience	nil	nil	Communications Manager (3.3 y)		3 y 3 m
Common courses studied during Master of Design: Semester I: Elements and Principles of Design, Ergonomics for Industrial Design, Art & Aesthetics in Design, Product Design, Visual Design, Design Workshop, Professional Communication Skills; Semester II: Interactive Design, Visual Ergonomics, Videography, Culture and Design, and Sustainable Design					
* G1M1 signifies Group 1, Member 1; 'y' signifies year; 'm' signifies month					

Figure 1. Group formation as per participant education and experience

Opportunity in Discarded Items

Unlike user-centric approach of industrial design methods (Ulrich, 2003), in the upcycling process the practitioner has to primarily deal with the *discard*ed materials that possess discontinuity and limited material characteristics. For understanding the affordance, the *discard*ed material has to be first divided in the form of perceivable entities. Accordingly, the initial phases of the DfD method facilitate the technical study of *discard*ed material followed by a practical exploration. Further, it was identified that a few design methods are inspired from the systems perspective, and divide the challenges into multiple segments till they become perceivable modules (Blizzard & Klotz, 2012; Khan & Tandon, 2015) to generate design concepts. DfD method facilitates processing and splitting of the *discard*ed material into perceivable modules, till they become simple enough to be studied. The process of splitting *discard*s is further elaborated in the upcycling case.

Further, the DfD method facilitates identification of local stakeholder(s), i.e., manufacturers and users, and locally adaptable manufacturing processes to limit the multiple and diverse considerations during the upcycling process (Tremblay, Gutberlet, & Peredo, 2010). Thus, the method assists design practitioners in identifying contextual issues related to the *discard* collection, *artefact* manufacturing, as well as *customer* requirements, and accordingly develop a design that can be circulated in the designated local context.

Stakeholder's Interest

In the present literature, only DfW work has considered and included manufacturing as an important factor, thereby, including marginalised communities in their method for cost-effective manufacturing of hand-made upcycled products. However, such communities will not be present in varying upcycling case(s), especially in the case of upcycling in developed countries. For example, TerraCycle invites and include volunteers (Szaky, 2014; Terracycle, 2016), Spiral foundation train and involve local villagers (Spiral Foundation, 2016), etc., as manufacturers of their designs. In contrast, 'manufacturing communities' (further referred as *artisan*), should be a generic segment to focus upon, to enable acceptance of a method to varying contextual set-ups of manufacturing. Accordingly, the DfD method would guide the design practitioners to identify the capabilities and limitations possessed by a probable *artisan group* based on their education, skills, experience, and motivation.

Customer preferences are one of the principal elements that guide an industrial design process and, also defines the fate of the designed product (Ulrich, 2003). Even though the manufacturing aspects of upcycled design are not comparable to the industrial design processes, yet the success of final upcycled design would be based on customer preferences (Sung, 2015). It has been identified during the literature survey that the number of customer considerations has to be limited to ease out the DfD practice. Norman had suggested that a design feature can be categorised into components that produce technical (function, usability, etc.) and emotional (aesthetics, sense of personalisation, etc.) effects (Norman, 2004). The proposed DfD process does not consider the design of technical requirements, and the novelty of the upcycled design is limited to emotional requirements only. Accordingly, a few of all the identified customer preferences should be taken so as to reduce the number of considerations in creative problem-solving. For the DfD method, the general requirements of regional customers towards the redesign of the existing products were identified, and the technical components were adapted from the relative designs available in the market. Further, the method facilitates the design practitioner to redesign the *artefact* with the emotional features only.

The Method Steps

In the context of design, a problem is said to be complex when the associated designer could not unravel the opportunities related to the identified factors, and, therefore, find it difficult to move to the next phase of problem-solving (Dorst, 2011, 2015). These circumstances occurred during the earlier practice on upcycling, i.e., W2D and DfW, where multifaceted considerations limited the design process and quality of outcome (Ordoñez, Khan, Tandon, & Rexfelt, 2016). For the DfD case too, the *discard*, *artisan*, *artefact* (the final upcycled product) and the *customer* distinct requirements and attributes that have to be meaningfully interconnected to proceed further in the design process. In spite of the fact that the generic industrial design processes cannot be directly applied to upcycling due to lack of inherent knowledge, the hierarchy of steps followed in the proposed upcycled process is inspired from the generic product development process (Ulrich, 2003).

If critically analysed, then for the concept ideation, it is essential that the participant can 'perceive' the interconnection between identified attributes (Yilmaz & Seifert, 2011). For example, a food packaging designer has to 'perceive' the identified food preservation requirements concerning the affordance of packaging material, to develop an appropriate concept. This interconnection becomes difficult for a practitioner to perceive in the absence of a guiding process (Wong & Siu, 2012), especially when multifaceted considerations are involved. To handle such concerns, the DfD method utilises the fundamental principle of 'splitting' the diverse information into comprehensible modules (Blizzard & Klotz, 2012). It is additionally supported by organising the modules in a relative hierarchy, and further analysing the modules in a comparative context. Figure 2 represents the seven-step DfD method, i.e., Draw-Identify-Split-Correlate-Associate-Rectify-Deliver collectively creating the word 'DISCARD'. The process is briefly presented with the help of Figure 2 to make a clear understanding of how the method steps were derived from the theoretical foundation.

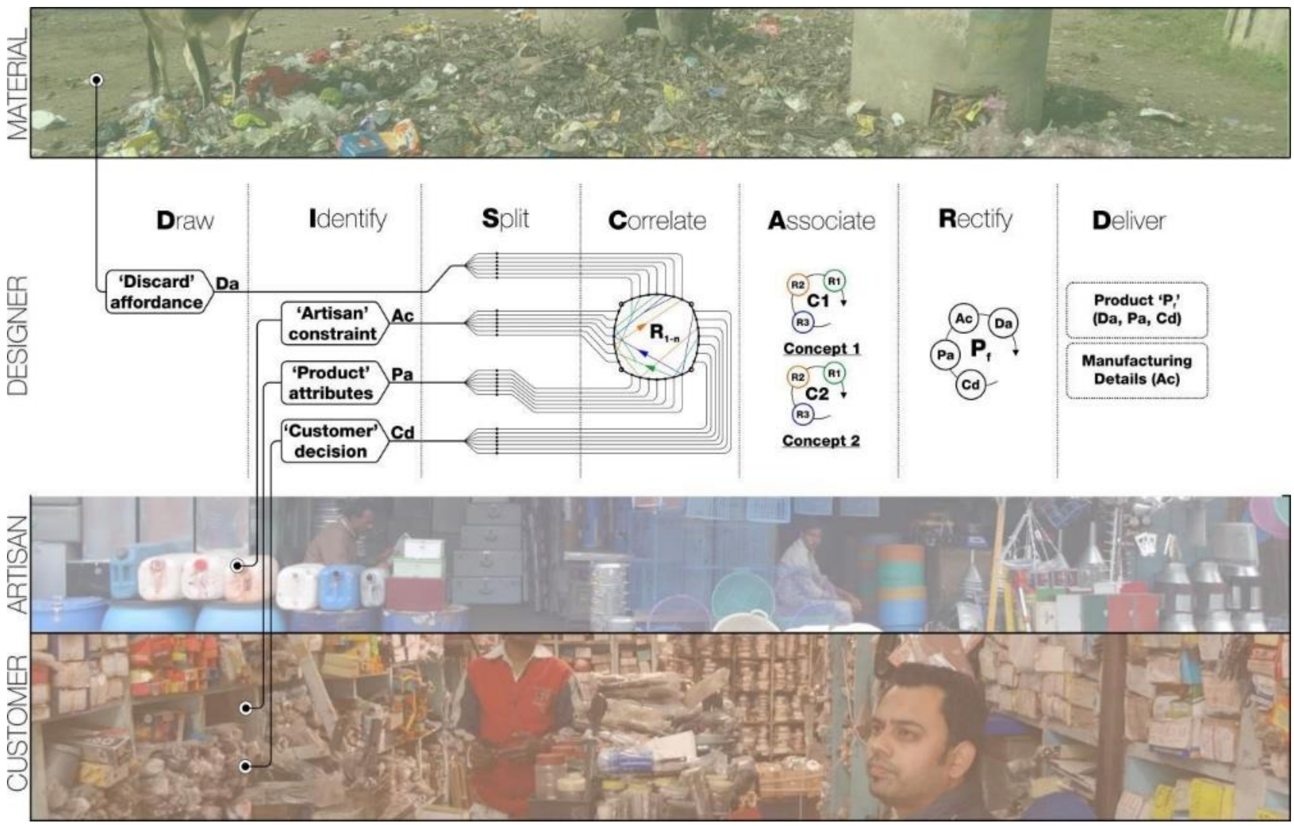

Figure 2. Design from Discard (DfD) method representation

The activities carried out in the individual steps are briefly introduced so as to make the process clear to the practitioners and other stakeholders:

- **Draw**: Design practitioners finalise a material collection site. They identify and collect *discards*, as well as study and analyse the *discard* properties.

- **Identify**: The step involves identification of local individuals and interaction with them to record and analyse their capabilities and limitations as an *artisan*. The step also involves identification of *customers* and *artefact*s of local importance to study their functional and emotional requirements to create new designs.
- **Split**: All the identified requirements of *discards*, *artisan*, *artefact*, and *customer* are categorised into separate groups. *Keywords* are assigned to the grouped requirements.
- **Correlate**: All the *keywords* are arranged in the form of the 'correlation wheel', where *keywords* and their pictorial representations assist the participants to review diverse information.
- **Associate**: The priorities of *customers* (as in the form of *keywords*) are connected with relevant attributes of the *artefact*, *artisan*, and *discard* respectively, creating the association for a concept generation. Similarly, other customer priorities are also connected, and separate concept modules are generated as well as combined to develop the final concept.
- **Rectify**: The generated concepts are cross-checked with the identified *keywords*, attributes, and requirements; the *artefact* is detailed and fabricated.
- **Deliver**: The developed *artefact* and details are handed over to the identified customer and *artisan*, and feedback is collected.

Design from Discard (DfD) Method: A Case Study

The knowledge of upcycling methods, industrial design methods, and stakeholder preferences serve as a foundation to develop the DfD method. The following scenarios are proposed, under which the design practitioners can suitably apply the method.

[Constraint 1]

The primary constraints to the application of DfD method for its successful implementation include fundamental knowledge of elements of design (e.g., point, line, shape, form, texture, colour, pattern, texture, etc.), and principles of composition (e.g., order, balance, hierarchy, etc.). These design fundamentals would assist the design practitioners in connecting the distinct characteristics of *discard*s, *artisan*, *artefact*s, and *customers*, and thus, it is important that practitioners have a prior understanding before practicing the method.

[Constraint 2]

As the method is based on the logical interconnections of distinct elements and attributes of *discard*s, *artisan*, *artefact*s, and *customers*, it is recommended to have a heterogeneous group-based activity to enhance the quality of the outcome. Moreover, the groups should discuss the procedures and the results at every stage to get diverse inputs.

The outskirts of Jabalpur city, in India, are selected as the *discard* collection site. Jabalpur is a densely populated sector and being a major city of the state, it practices a waste management policy and regulations (CPHEEO, 2016). In spite of such installations, the packaging waste disposal is a common issue here and, therefore, motivates the globally comparative platform to initiate the DfD practice. Moreover, a considerable population of Jabalpur is semi-skilled and unskilled individuals, having limited employment options (*Census of India*, 2011; Nandy et al., 2015), and therefore, could participate as manufacturing stakeholders.

[DfD Method Step 1] Draw: Design Intent and Material Knowledge

In DfD method, initially, the practitioners were expected to realise the environmental effects, such as waste generation and accumulation, of industrialisation and consumerism. It is important to create a practical foundation for the participants to drive them effectively towards DfD practice. Various unrecovered materials should be collected from the selected waste disposal site for further off-site exploration. The off-site exploration should include the macro study of the factors that are responsible for the particular waste generation and accumulation. This analysis should be further narrowed down to understand product life stages, e.g., design, manufacturing limitations, production optimisation, transportation efficiency, etc. of the identified *discard*. The documentation of these *discard* characteristics should be focused on the *discard*ed materials, not constrained in any predefined direction, to let the participants come up with unbiased findings.

Figure 3(a) shows the community waste disposal site at Jabalpur, India for the on-site material collection. The participants collectively visited local waste disposal sites and identified *discard*s that were left unattended. The collected *discard*s include light-weight metallised films and multi-layered flexible packaging, poly bags, and laminated paperboard that can be referred in Figure 3(d). Some of the complex items like sanitary pads, degraded paperboard, contaminated cardboards, etc., were not collected due to the risk of health hazards. Figure 4 shows the details of quantitative characteristics identified from the regional database (Indiastat, 2016) and as well as field study. Further, the collected materials were sterilised and sorted to identify the actual quantity of *discard*s generated from a single disposal site each day. The various factors that limit the recovery of collected *discard*s were studied and documented.

Another planned site visit, to a local recycling facility, followed the on-site material collection and off-site material research. The motive of the visit was to explore and ascertain the reason behind the accumulation of identified *discard*s, in spite of the availability of the locally existing material recovery options. In this case, the participating teams visited various end-life locations of the multi-layered packaging systems and services. Figure 3(b) and 3(c), shows the visit to a local scrap recycling unit and scrap vendor garage that was performed to identify the collectibles and discards based on their market value. This stage of the method also created a technical foundation within the participants about the collected *discard*s.

Figure 3. (a) Selected community waste disposal site; (b) Survey of recycling sector; (c) Study of collectibles at scrap vendor garage; (d) Selected discard samples

Characterstics of discards			
Collection		**General**	
Total number of household for each disposal site of ward (Statistical database)	**233**	Combination of material (from outside to inside)	**PET/pigment color/Aluminium film/PET**
Total number of household for each open disposal site (Field Study)	**254**	Density (gm/cc)	**1.4**
Quantity of household solid waste generated in each ward	**720 Kg/day**	Thickness (microns)	**12**
Quantity of total packaging waste (1.21 % of solid waste)	**8.71 Kg/day**	Technical name of material	**Metallized PET**
Total multilayered packaging collected from site (non-contaminated)	**2.12 Kg**	Packaging producers (as mentioned in packaging)	**Various states in India**
Cleaning and Sorting		**Mechanical**	
Total PFP accepted after cleaning and sterelization (percentage/weight in gms)	**57/1208**	Tensile strength (Kg/cm^2)	**1800**
Total percentage of materials selected even after cutting/sorting/rejecting (percentage/weight in gms)	**25.34/530**	Elongation (%)	**70**
		Thermal	
		Shrinkage @ 150 C/30 mins	**2**
		Melting point (Deg C)	**250**

Figure 4. Characteristics of discard explored during the onsite and offsite study

[DfD Method Step 2] Identify: Stakeholder(s) and Scope for Re-purpose

This section of the method assists us to collect the desired information and characteristics about the stakeholders, i.e., *artisan*s and *customers*. The effectiveness of DfD method depends on the involvement of the participants, and therefore, meaningful interaction with the *artisan*s and *customers* is the primary step to engage the design practitioners for gathering insights.

Quantify Artisan's Need

For the multi-layered packaging project, the local 'rag pickers' involved in the unorganised waste management activities were identified as *artisans*, as they were closely related to the present waste management practice. However, the method is not limited to any particular group, and other projects performed by different groups identified different social groups as *artisan*s, e.g., construction site workers, hawkers, etc., for their cases. The manufacturing of designs would involve various processes and may require training during commercial use and, therefore, the information on the capabilities, i.e., physical capability, intellectual capability, literacy, income, prior experience, motivation, external factors, etc., are relevant to determine and measure the performance of the *artisan* group. In this way, one can further manage the workforce, tools, time and other pertinent parameters during organisational application. For this purpose, focus groups, questionnaire, and structured interview techniques can be carried out.

An interaction of practitioners was scheduled with *artisan*s to sensitise and raise awareness about the working and living conditions of the potential *artisan*s. Figure 5 represents the summarised results of the questionnaire carried out by participants on five *artisan* families regarding general information, skills and experience, familiarity with tools and techniques, educational qualification, and motivation to engage in the upcycling process. Besides, the present wages of the *artisan* group is also compared with that of the international standards (International Labour Office, 2014; Labour Bureau, 2010) to measure the economic feasibility of the upcycling case. The questions can be further categorised regarding stages of life-cycle, physical and intellectual capabilities, income, and investment potential, etc., according to the contextual requirements.

These data were further sorted and categorised during the next step.

Quantify Customer's Need

The design practitioners were first expected to identify the product(s) of considerable local demand and select one of them for a redesign. Besides, a certain customer group should also be identified that may be interested in the new intervention on the chosen product. The practitioner should also access their knowledge and experience and then select a product for a redesign. It is also recommended that the product should not have complex functional elements. Further, the chosen product should be studied regarding its functional and emotional elements. To limit the number of constraints, the functional elements should remain constant and, the selected designs should be evaluated within the context of emotional elements only. Additionally, practitioners can explore the locally popular art forms and trends that could be implemented in the redesign to influence customer preferences.

Figure 5 represents the selection and survey of the customer. The undergraduate practitioners of the university were selected as a customer during a discussion of group members for the reason that the DfD process may lead to non-obvious redesigns, and valuable insights can be expected from undergraduate level practitioners since they have a comparatively better intellectual ability. Further, the group members selected the options of existing products such as tote bag, sheet folder, umbrella, and shoe cover, after an interactive session about their background knowledge and the relative feasibility of redesign. Umbrella was finalised for the redesign, and the emotional redesign was limited to ‘canopy of umbrella’ as the surface characteristics of canopy match with that of the selected multi-layered packaging.

Artisan' characterstics		**Customer' characterstics**	
General		**General**	
Total subjects surveyed	12 people above 21 years, in 5 families	Total subjects surveyed	27
Present profession of artisans	rag-pickers	Profession of customers	Undergraduate students
Educational Qualification (minimum - maximum)	Uneducated - Grade 5	Educational Qualification (minimum - maximum)	Grade 12
Age group (years)	23-42	Age group (years)	19-21
Sex	9 Male and 3 Female	Sex	18 Male and 9 Female
Skills and Experience		**Redesign details**	
Experience	Various experience related to labour work and ragpicking	Product options selected by participant students based on discard characterstics	Tote bag, Sheet Folder, Umbrella, Shoe cover,
Familiarity with handicraft tools	General tools such as hammer, scissors, adhesives	Selected product for redesign	Umbrella
Motivation		Parts of Umbrella to be borrowed from existing designs	Telescopic Shaft, Rib, Runner, Strecher, crook handle, knob, lock unit
Reason for participation	Financial sufficiency	Part of umbrella for redesign	Canopy
Present daily wage	USD 1 - 1.57		
International standards for daily wage	USD 4-13		
Direct inverstment capability	USD 10 - 14		

Figure 5. Characteristics of artisan and customer identified during the survey

[DfD Method Step 3] Split: Categorise and Abbreviate Information

With reference to a generic product design and development process, the collected information and characteristics on *discard*s and stakeholders have to be converted in the form of *needs* and further into *design features*. In the ‘split’ step of DfD method, all the collected information should be split, organised and analysed in a relative context till the information is simple to perceive. ‘Splitting’ for the *discard* affordance, the need for *artisan*, the features of *artefact* and the need of *customer* should be altogether independent of each other. For example, it is highly recommended that the selected *discard*s should be tinkered and if possible, physically split in the form of design elements, like, point, line, shape, form, colour, texture, etc. Moreover, the material has to be split into its compositional elements. Figure 6 represents the split process for a multi-layered packaging project, where subcategory of Design Primitives, consists of a point, line, texture, etc., as abbreviated *keywords*. Similarly, ‘split’ is performed for other identified requirements of *artisan*, *artefact*, and *customer*.

Further, in the split process, the participants were also required to abbreviate the information(s) into generic ‘keyword(s). For example, during ‘split’ of *discard*s, various techniques that bind the *discard*ed material can be abbreviated as ‘joining tools’ that can be referred in Figure 6. Such abbreviations support the design practitioners to recall the detailed information as and when required. For the collected multi-layered packaging materials, the splitting of *discard* was based on knowledge of design fundamentals, mechanical and physical properties. Therefore, all the information is first subcategorised as *Design Primitives*, *Mechanical Properties,* and *Physical Properties*. Figure 6 shows that every identified requirement is abbreviated with the *keywords*. The other *keywords* were derived on the basis of critical discussions carried out the practitioners.

Customer' Requirements		Artifact' Qualities		Artisan' Constrains		Discard' Affordance	
Subcategory	Keywords	Subcategory	Keywords	Subcategory	Keywords	Subcategory	Keywords
Priority 1	Personalization	Functional Attributes	Parts (quality)	General Tools	Workbench	Design Primitives	Point
Unique Selling Proposition	Uniqueness		Parts (quantity)		Ruler, Clamps		Line
	Apeal		Compatibility		Spanner		Shape
	Trend		Use-cycle		Wrench, Pliers		Form
Priority 3	Durability		Finishing Quality		Hammer		Texture
Usability / Functionality	Comfort	Aesthetic Attributes	Local Art Form	Cutting Tools	Hand Drill		Pattern
	Usability		Neo-art		Cutting Tools		Space
	Added features		Polygon art	Joining Tools	Punch, Rivet	Mechanical Properties	Flexibiity
	Quality	Contextual Issues	Behaviour		Adhesives		Tempreture Effect
Priority 2	Price Benchmarking		Scenario		Lamination		Elasticity
Purchase Decision	Affordability		Error	Precision Tools	Measurement		Plasticity
	Mental Model		Cognitive		Geometry	Phyical Properties	Optical
			Working conditions	ILO Specification	8 Hours/day		Detoriation
			Weather		INR 250/day		Corrosion
							Electrical

Figure 6. Keywords derived from information collected during stage 1 and stage 2 of DfD method

[DfD Method Step 4] Correlate: Create Significant Relationships

A unique correlation wheel was developed to facilitate the meaningful correlation of *keywords*. As shown in Figure 7, all the identified *keywords* can be categorically arranged on the wheel along with the pictorial representation. The correlation wheel shows the four categories, i.e., *customers, artefacts, artisans,* and *discard*s, and their subcategories based affinity among *keywords*. Since all the *keywords* and a graphic representation were listed on the correlation wheel, it is advisable to begin the task of prioritising the subcategories of customer section. These priorities have to be assigned to a group of *keywords* of customer category, concerning their influence on customer preferences as earlier explored during the questionnaire session of *identify* stage. The practitioners should perceive a feasible way of connecting the *keywords* of customer category with that of *artefact* category only, rather than focusing on developing a tangible solution at that stage. In this way, a connection would be established through most of the *keywords* that would lead to the development of justified concepts in subsequent stages. The correlations can be colour coded for explicit representation of relationships.

Figure 7 provides a clear understanding of the use of correlation wheel that was derived for the case of multilayer packaging project. For some of the *keywords*, a pictorial representation is also illustrated to facilitate better recall of information on artefact characteristics. In this project, the latest trends and local art forms were taken as a priority to influence the customer through aesthetic redesign of the product. Similarly, all the customer *keywords* were prioritised (as shown in Figure 7 with the labels P1, P2, P3), and connected to the *keywords* of the *artefact*, *artisan*, and *discard*, simultaneously. The practitioners have to consider whether interconnected *keywords* are creating a meaningful feature of the concept. Each relationship (shown in Figure 2 as R1-Rn) represents the conceptualisation of prioritised requirements of the *customer* in an *artefact* using available *artisan* and *discard* characteristics. For example, in Figure 7, the keywords in *customer* section which are named as *personalisation, uniqueness,* and *trend*, are connected to keyword *polygon art* of the *artefact* section, which leads to the hint for practitioner that the *artefact* could fulfil the targeted *customer* preferences if relative keywords are considered and connected from the *artefact* category. The arrow direction shows the dependency of the tail keyword with the head keyword.

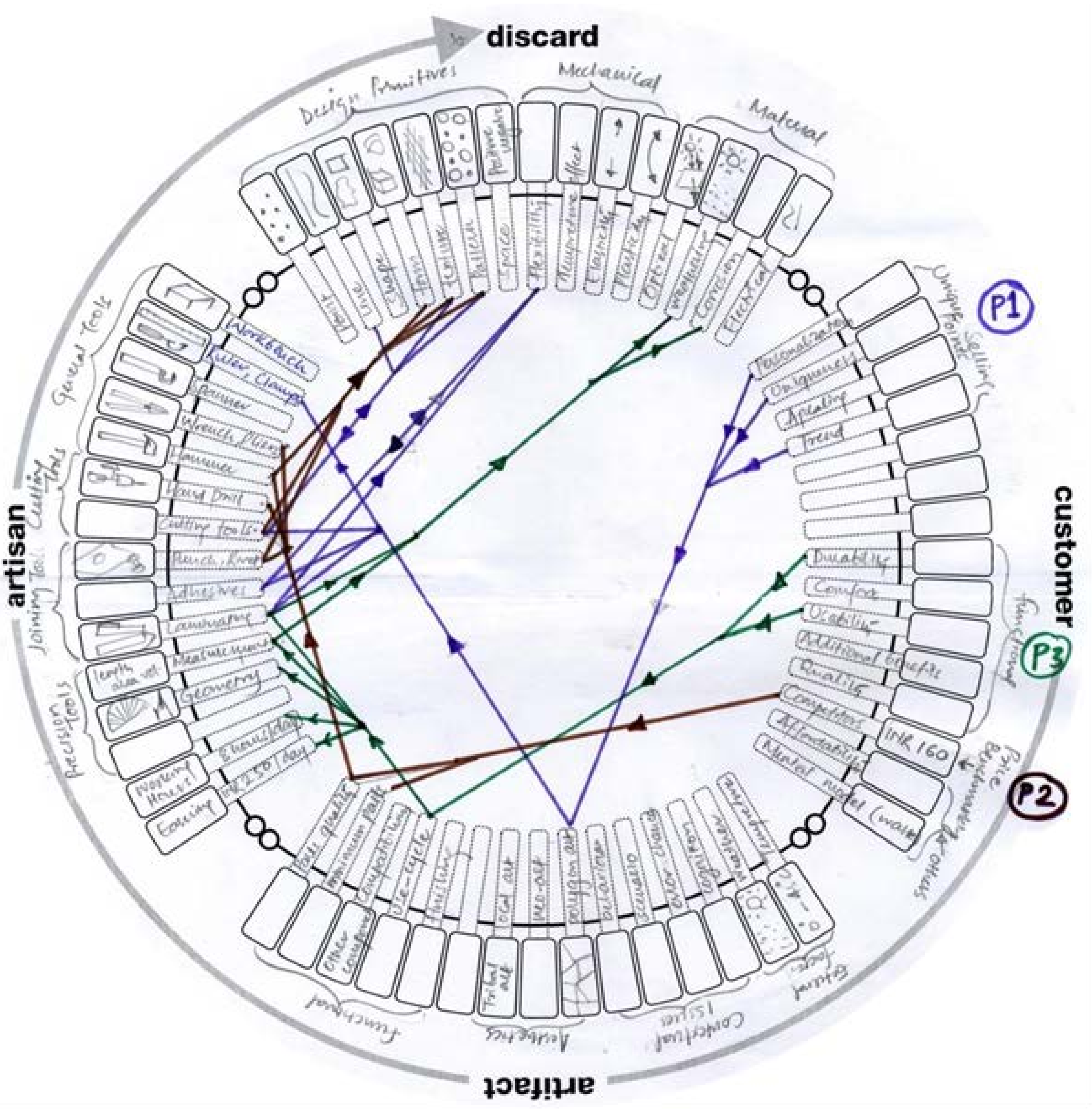

Figure 7. Correlation wheel representing priorities and relationships of keywords

[DfD Method Step 5] Associate: Justify Interconnections and Generate Concept

By the correlate stage, the design practitioners should have a clear understanding of the correlation of *keywords* and how it would lead to a concept feature during conceptualisation. The practitioners should collect all the documented information, *keywords*, relationships, and correlation wheel, and place them in a common workspace. During conceptualisation, the exploratory concepts should satisfy all the *keywords* that have been connected for the identified priorities (shown with the help of colour code in Figure 7 as P1, P2, and P3). This activity of conceptualising relations (referred in

Figure 2 as R1, R2, R3… Rk) leads to the first visible representation to fulfil requirements of *customer*, *artefact*, *artisan*, and *discard* information. The participant teams should develop independent *concept modules* for all these *relations* and then should try to merge these *concept modules* in the form of concepts (referred in Figure 2 as C1 and C2).

Figure 8(b) represents the process performed by the practitioner groups, to explore the final form and functionality of the concepts. For testing the manufacturing feasibility of the concept, the participants used various tools, e.g., general tools, precision tools, measurement tools, cutting and splitting tools, adhesion and joining tools that were identified during the *Identify* step of the process that can be referred in Figure 8(a).

Figure 8. (a) Tools identified for manufacturing; (b) Practitioners fabricating the selected concept

[DfD Method Step 6] Rectify: Test and Detail the Concept

During the evaluative research of a product design process, a concept prototype has to be tested in the actual context of use to overcome its shortcomings, before the design is detailed (Ulrich, 2003). However, mere comparing the prototype with identified issues is not sufficient and, therefore, prototyping and testing have to be performed as well. In the DfD method, *Rectify* step has been introduced to simulate the actual conditions, and to explore the overlooked issues in the selected concept. An exciting activity is developed to recognise the hidden issue(s). The design teams developing different projects may be further advised to exchange their final prototypes and train the other teams to manufacture the design as *artisan*s and use the products as *customers* to obtain different insights that might have been overlooked by the team that had developed the product.

During the redesign project, initially, the practitioners performed a cross-check and found the concept prototype C2 satisfying the most of the documented requirements. Different teams exchanged their information, assuming the other team as the actual *artisan*s. The other design teams perceived themselves as the imitating *artisan*s, and adapted to the *artisan*s' conditions, i.e., physical, intellectual, and financial conditions, as identified earlier during *Identify* stage. The actual design team trained the imitating *artisan*s, with the upcycling activity. A few unique insights were collected when practitioners were imitating the manufacturing activity as *artisan*s that were not perceived initially by the actual design team. Similarly, some issues regarding product usability were also identified. The observed problems were related to the finishing quality and improper usability. Further, a discussion based interaction between all five groups, which was performed to cooperatively rectify the newly identified issues that were missed by the 'individual' design teams. Finally, the concept was detailed, and a final upcycled design was developed.

[DfD Method Step 7] Deliver and Feedback

To further justify the developed prototypes on the identified requirements, a pilot study of *customers* and *artisan*s was performed. First, the upcycled design was analysed for the final cost and technical performance. The *artefact* was handed over to the actual *artisan* with the intended training, tools and techniques and process details, and the insights were documented. Further, an in-house session with the potential *customers* (as identified during the early stage) was organised to collect valuable insights on the final design.

Figure 9(a) and 9(b) shows the redesign of the umbrella made out of defined metallised packaging film that was shown to *customers* for feedback. The *customers* were asked questions concerning the aesthetic and usability features of the final redesign. The *customers* were also provided the upcycled umbrella for practical exploration. As shown in Figure 10, all the other practitioner groups selected different *discard*s, follow the DfD method and were able to create diverse redesigns.

Figure 9. Umbrella made up of metallised packaging discards

Figure 11 represents the reflection of the final design of concerning practitioners (collectively for each group), *discard*s, *artisan*s, *customers*, and *artefact*s. At this stage of the method development, the success can be measured with respect to confidence in achieving the intended objectives. The primary objective of this project was to propose an upcycling-based method that considers the contextual issues regarding *discard*, *artefact*, *artisan*, and *customer*, and reduce uncertainty, and provide quantitative and qualitative measures to result in a final product.

Figure 10. (a) Fruit Basket made of Tetra Pak by Group 2; (b) Stick for security guards made of perfume bottles by Group 3; (c) Utility basket made of Tetra Pak by Group 4; (d) Sound amplifier made of laminated paperboard by Group 5

Design Practitioners	Discard	Artisan	Customer	Artifact
Twelve weeks is the total duration taken by Group 1 to complete the project	A total of 42 grams of discards were used in each umbrella redesign	All the identified 12 artisan participated in the feedback study	All the identified 27 customers participated in the feedback study	Additional 40 microns PP (polypropylene) (108 grams by weight) is used as base material in canopy
All the five projects were completed in the scheduled time, expect 1 week lag for 2 groups G2 and G5	12 umbrella canopy can be manufactured/MSW disposal site/day	58%, i.e. 7 artisans were able to develop the design with the selected tools	Usability aspects of redesign was accepted by 81% (22 subjects)	Total weight of redesign increased by 27% as compared to 210 grams of the selected umbrella
Selection of discards and stakeholders substantially affected efforts put-up and time-taken	About 77% of the collected discards is wasted in cleaning and sorting	2 hours 20 minutes is the time taken by artisans to manufacture the design	Aesthetic aspects of redesign was accepted by only 11% (3 subjects)	The canopy redesign stood fit against sunlight and, is found waterproof during test
Engaging students directly is hazardous and better ideas are required for safe discard collection		3-4 umbrella can be manufactured in an 8 hour workday		Opening and closing of canopy demands effort as the thickness of canopy is increased
		USD 14.53 is the total cost of tools and additional used to manufacture the redesigns		

Figure 11. Reflections of the final up-cycled design with respect to identified multifaceted considerations

Findings and Discussion

This research work has presented a method Design from *Discard* (DfD), that guide design practitioners to handle multifaceted considerations, and accordingly, deliver an upcycled design. To propose a design research considering the elaborated multifaceted aspects is challenging yet vital requirement to commercialise upcycling practice. The existing works in literature have proved that upcycling through design education is an effective way to boost upcycling practice. However, they lack methodological details to reduce the uncertainty and to lead to a final product.

The few available ‘initial’ methods provide a foundation to practice DfD methods, such as the inspirations from generic design process for upcycling, the effect of participant’s prior experience, and manufacturing considerations. The DfD method further attempts to resolve the issues that limit the existing methods to lead to a final design. The most important issues being the handling of ‘discontinuity’ in *discard*s, limiting uncertainty in creative problem solving, and incorporating the needs of the *customer* and *stakeholders*. In the theoretical foundation, we justified the need for a detailed process that provides quantitative and qualitative parameters to ensure the progression of step by step process.

The project-based coursework initiated a comparison of education and experience of the group members to create heterogeneous groups. One of the important aspects of DfD method is to motivate the design practitioners towards the actual waste management conditions to result in their active participation in the process. We can say that the practitioners are the connection between the DfD method, *discard*s, and stakeholders. Thus, this method indirectly attempts to propose an ecosystem to propagate the idea of collaborative upcycling for a widespread outcome. The enthusiasm of the practitioners during initial steps of ‘Draw’ and ‘Split’ was visible and positively affected their participation in the process. The later steps of ‘Rectify’ and ‘Deliver’ demonstrate the applicability of the solution for the identified needs, and also shows the involvement of the practitioners in the DfD process to deliver the outcome. Each week of the coursework was appropriately scheduled, and participant groups were able to complete the project in the defined time. However, two groups G2 and G5 had three members, were lagging behind and were given one-week extra time for completion. The quantitative and qualitative measure regarding practitioners can be studied and implemented in future works.

The participants collect the materials directly from the waste disposal sites in the proposed work. It involves health hazards, and some of the practitioners did not find the interaction hygienic. Further, the method also includes an additional step where the practitioners sterilise the collected materials and sort it. However, the demonstrated activities serve as a way to sensitise the practitioners with actual issues in material recovery that can be referred for future works. In further improvement for hygienic waste collection and sorting, there can be an incentive-based direct collection of household waste material (see for example Janwani, 2016; TerraCycle, 2016), in accordance and suitability with local service and system. Presently, the quality and quantity of the material have been explored by the practitioners with an engineering background in each group. However, there is a vital need of database on material properties to ensure the desired performance of *discard*s in an upcycled design.

Regarding the manufacturing stakeholders, the DfD method provides flexibility to identify local communities that can act as an *artisan*. The method is successfully applied to other cases as well (refer figure 10), where the participants selected varying *discard*s, and *artisan*s to develop other design solutions. However, we found it difficult to train the identified *artisan* community, during the 'Deliver' step and most of the *artisan*s were unable to reproduce the designs with the desired level of precision. The method is currently practiced through variable practice sessions to enhance the quality of outcomes during manufacturing. Moreover, additional studies can be performed to analyse the opportunities and constraints with *artisan*s to practice the upcycling for their living. The effect of *artisan*'s skills, prior experience, physical ability and the financial requirement in the upcycling process, is another important and exciting domain to study to steer upcycling practice for employment generation.

In the presented illustrative case, other than the technical details of materials, the practitioners have to test the various *affordance*, i.e., design attributes, physical properties, flexibility, etc., of the collected material during the 'Split' step. In a few of our cases, mere characterisation of material affordances in the predefined arrangement hindered creative exploration. We identified that for effective exploration practitioners have to individually tinker with the *discard*s to understand the physical behaviour. This activity of tinkering with the material is crucial, and ample freedom should be given to study and record the material affordance. There are many tools and methods of material affordance exploration which can be introduced to facilitate material exploration. For instance, Expressive Sensorial Atlas (Rognoli, 2010), and Material Driven Design (MDD) (Karana, Barati, Rognoli, Der Laan, & Zeeuw, 2015; Pedgley, Rognoli, & Karana, 2016) facilitate material sensorial understanding with respect to technical properties and therefore, can enhance the application of *discard*ed materials.

Particular attention was given to abbreviate information for the correlation wheel, where the information gathered during *Draw* and *Identify* stage were converted into *keywords* with minimum infographics. The unique 'correlation wheel' has come out to be a useful tool to handle multifaceted considerations. However, the correlation wheel was confusing for some of the participants and sometimes, they found themselves deviated from the actual motive of *prioritising* and creating *relationships*. Another set of practices on utility and detailing of correlation wheel, and maybe a measure of the effectiveness of the wheel can be significant research works.

The DfD method suggests a sequence of steps (Draw-Identify-Split-Correlate-Associate- Rectify-Deliver) to be conducted during the design process. For the illustrated redesign projects, the practitioners were advised to choose functionally simple products that have a considerable market acceptance. We identified that the suitability and acceptability of the upcycled solutions highly depend on the nature of the project, e.g., time concerns, team size, team expertise, material quality, the requirement of the stakeholders, etc. For example, in a few cases, the *discard* is collected from a comparatively organised waste stream, where the scope for material affordance was increased. Similarly, in one of the cases, the identified *artisan* was capable of relatively greater capital investment on initial setup, and accordingly, practitioners had more flexibility to incorporate better features, e.g., technology adaptation, trend, material finish, etc., that in turn increased the acceptance of the product for the customer. We predict that in a further application, the resulting solutions from the DfD method will create new knowledge of material and stakeholders.

The motivation behind the work is to propose a general upcycling intervention model that can be utilised by various intellectual groups to contribute to mass *discard* recovery in the form of upcycled goods. The success of this motive is a future concern and is dependent on the practice and improvisation of method and acceptability of upcycled solutions to the *stakeholders*. This work is limited to proposing the action steps for the DfD method and shows that how uncertainty in upcycling can be limited and solutions with defined performance parameters can be achieved.

As shown in Figure 11, the resulting upcycling design was shown to the customers and artisans during feedback sessions. The usability aspects of the design were accepted by 81 % of the participants, however, the aesthetic aspects of the redesign were accepted by 11% of the subjects. This means that further improvements are required regarding aesthetic quality, detailing, and finishing of the outcome. However, this work provides answers to the prevalent uncertainty related aspects related to upcycling with the support of an academic setting. The work also established a teaching-learning pedagogy for upcycling practice in institutions, where, practitioners can collaborate with stakeholders in unique ways to upcycle discards. Application of DfD method to other context, materials, stakeholders, etc., would bring new insights and help to refine the method for the overall (i.e., people, planet, and profit) sustainability perspective.

Upcycling has the potential to compete for the quality industrial design, nonetheless, in the absence of inclusive design research, assistive technology, and capital investment, upcycling-based initiatives struggle to initiate and perform efficiently. The present literature and the DfD method shown here are the initial attempts to support upcycling through design education. It is evident that the upcycling and, the related system and services should be evolved with time to result in visible changes. For example, currently for the presented case, *discard* collection is performed at the municipal solid waste sites, that could be further enhanced to invite packaging and recycling industries to aid take-back loops. Numerous in-depth technical tests regarding the business model, sales, and promotion, as required to standardise further operations and procedures for developing a marketable upcycled product. Additionally, the method might provide a broad range of opportunities to step-up a local upcycling based enterprise, resulting in individual and organisational upcycling initiatives.

Conclusion

This paper presents a novel method to support the design practitioners in resolving challenges to upcycling. We have presented a design method entitled Design from *Discard* (DfD), which assist the design practitioners in exploring opportunities with *discarded materials* and *stakeholder(s),* and accordingly, develop a suitable design solution. The DfD method comprises of seven main steps, namely: Draw, Identify, Split, Correlate, Associate, Rectify, and Deliver, collectively the acronym 'DISCARD'. The elaborated case represents our first attempt to resolve the issue of uncertainty of *discard*s, and hindrance in upcycling that is because of multifaceted consideration prevalent in the existing literature. The method is demonstrated by an illustrative case of 'redesigning an umbrella' with *discard*ed 'metallised packaging film' suitable with characteristics for the identified *artisan* and *customer*.

The upcycled designs possess the details regarding the *discard* and *stakeholders*, limit the uncertainty in the design process, and provide a measure of the effectiveness of the final upcycled design, which has not been identified in the examples of the existing literature. The usability aspects of the final design are satisfactory. However, the aesthetic aspects of the final design are not acceptable to the identified customer. Also, the participants' intellect, experience and skill set, are few of the defining parameters based on which the effectiveness of the final design can be ensured. Application of DfD method to other context, materials, stakeholders, etc. would bring new insights and aid to refine the method for the, people, planet, and profit sustainability perspective.

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23.2

Medical Device Design Education: Identifying Problems Through Observation and Hands-On Training

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Key words

design education; observational learning; experiential learning; hands-on training; medical simulations; need finding

Abstract

Experiential learning, which may include hands-on learning paired with observation and reflection, has been applied in several industries; however, the impact of experiential learning in design education is not well known. We investigated how the type of simulation-based learning could affect the acquisition of knowledge and the ability to synthesize that understanding into insights for medical design innovation. One workshop included observational learning and the other experiential learning with hands-on training. Each course included 14-16 multidisciplinary undergraduate and graduate students. During both workshops, we measured student comprehension of two procedures— infant resuscitation and management of maternal hemorrhage. We focused on the first two phases of design thinking: “Understanding” and “Defining the Problems”. Although the course focused on “medical device design”, we encouraged students to look beyond the tool to imagine how their design change could impact the entire system. We did not find a significant difference between the scores given to students in the two courses by industry experts. Although the quality of the ideas and execution were similar between both workshops, the instructors noticed that the integration of hands-on training into the second workshop created a higher level of excitement in the class. The methodology and the approach adopted may be relevant to many design problems. In order to better understand the impact of observational learning versus hands-on training, both workshops could be expanded into full quarter classes that allow students to expand their design thinking skills to prototype and test their ideas in the real world.

Introduction

Experiential learning, which may include hands-on training paired with observation and reflection, has been utilized in other disciplines such as business, psychology, military and aeronautics (Crawley, Brodeur, & Soderholm, 2008; Gosen & Washbush, 2004; Seaman, Brown, & Quay, 2017; *The Handbook of Experiential Learning and Management Education*, 2007). However, the impact of experiential learning in design education is not well known. In this study, we sought to understand how observational learning versus experiential learning may impact a design student's comprehension of a medical procedure as well as their capacity for need-finding and innovation. During two different workshops, we purposefully contrasted observational learning with experiential learning that included hands-on training. Observational learning is defined as learning by observing others. Conversely, experiential learning is "the process of making meaning from direct experience, namely learning through reflection on doing," (Felicia, 2011, p. 1003)

Experiential learning can occur in the field or in a simulated environment. Some university programs allow design students observational learning experiences through field immersion. For example, Georgia Institute of Technology has partnered with Emory University School of Medicine to offer design students the opportunity to learn through immersion at the hospital (Ackerman & Schaar, 2016). However, they did not include a hands-on training component. Beyond auditory and visual learning, hands-on training offers design students a kinesthetic experience. The ways people receive information may be divided into three categories, sometimes referred to as modalities: visual—sights, pictures, diagrams, symbols; auditory— sounds, words; kinesthetic—taste, touch, and smell. An extensive body of research has established that most people learn effectively with one of the three modalities and tend to miss or ignore information presented in either of the other two (Felder & Silverma, 1988). In this study, we explored the impact of experiential learning through simulation on design education.

Simulation learning fits well within the design-thinking paradigm ("An Introduction to Design Thinking Process Guide,"): empathize (through immersion), define (the needs or problems), ideate (rainstorm), prototype (iterative low resolution style) and test with users (repeat). Two experimental medical device design workshops were co-taught by a lecturer from the Hasso Plattner Institute of Design and clinicians from two children's hospitals. Both workshops aimed to inform the Safety Learning Lab for Maternal and Neonatal Care and the d. School teaching community the differences in problem comprehension and solution development when students did observational learning versus observational learning and hands-on training. Our hypothesis was that used in the context of design education, hands-on training with medical simulations may lead to more effective and safe product or system development by helping designers develop a deeper understanding of what clinicians have to do step-by-step to achieve a desired outcome. Although this research was conducted in a medical context for the purpose of designing safer and more effective medical devices, the methodology and the approach adopted may be relevant to many design problems.

Objectives and Research Questions:

In this study, we investigated how the type of simulation-based learning (observational learnings versus hands-on training) could affect the acquisition of knowledge and the ability to synthesize that understanding into insights that can contribute to medical design innovation. At the d. School, our healthcare design classes purposely avoid giving interdisciplinary students information regarding aspects of a procedure that need attention, instead relying on the student's ability to identify needs through their unique academic lens. Our study posed the following two questions:

1) Which mode of learning led to deeper insights and the identification of latent needs?

Often, these needs aren't so easy to find. Moreover, when we can find out a reasonable set of needs, we often have difficulty translating them into appropriate solutions to both find important needs and develop them into compelling solutions. It's necessary to move beyond what we can tangibly sense into more abstract realms of concepts, frameworks and ideas.

2) How did the mode of learning affect the quality of the solution ideas?

The term "quality" refers to "kind" rather than "high quality" or "poor quality".

Conceptual Background:

Needfinding is the act of discovering people's explicit and implicit needs so that you can create appropriate solutions. Looking for needs rather than specific solutions keeps all possible solutions open for consideration and avoids prematurely limiting possibilities. In our workshops we asked students to first state needs independently of ways those needs might be served (Patnaik, 2016).

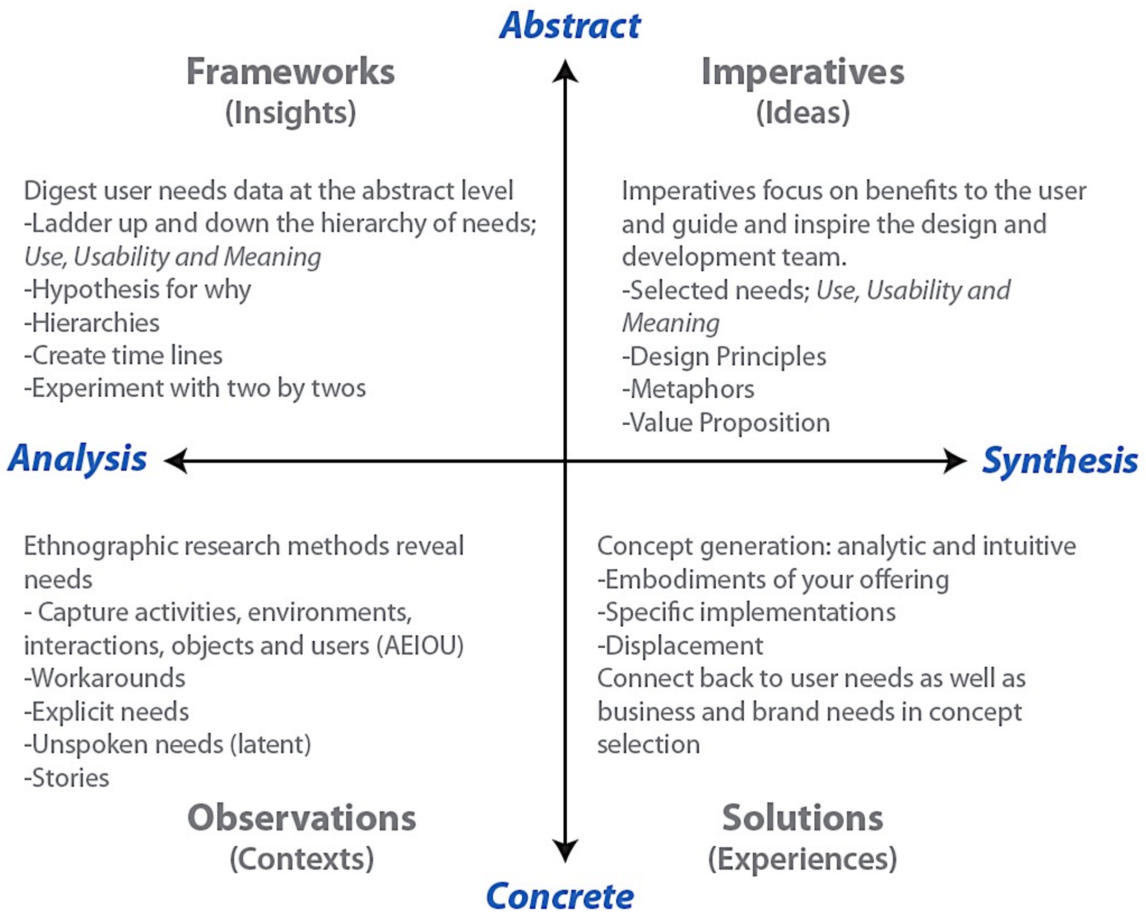

Figure 1. Experimental Learning Theory.

Figure 1 is a two by two diagram that organizes the design thinking process into four quadrants. Stanford's d. School uses this model that connects two bodies of prior academic work--a design model first proposed by Charles Owen at the Illinois Institute of Design and David Kolb's experimental learning theory. In our workshops we touched on each of the four quadrants, but focused on the "Observations" and "Frameworks" sections.

Researchers obtain the richest information on people's needs by observing and interviewing users first-hand. The researchers can then directly see many small but important details about the user's activities and the context in which they occur—details that wouldn't be available outside that context. By directly observing users' activities, need-finding avoids reliance on user's' memory, descriptive ability, or awareness of a need. In addition, the user's environment facilitates communication between the researcher and the user by allowing them both to refer to and use objects in the environment during the discussion (Patnaik, 2016).

Once data are collected, the final stage of the need-finding process is to interpret the findings and categorize the needs through creating a hierarchy (synthesis). Information collected in the user's environment helps refine one's understanding and prepares the team for another iteration of research. Product development can then continue in parallel to the ongoing need-finding activity. Because need-finding is about studying people, as well as developing products, we frame interpretations in terms of what problems need to be solved to improve the user's situation (Patnaik, 2016).

The ability to discover important insights may suggest areas of innovation for designers, as well as new markets that await development. The result of practicing need-finding techniques can be applied to the recognition and refining of user workarounds, and inventing innovative new solutions that leap past incremental change (Patnaik, 2016).

At the d. School, experimental hands-on project courses give students practice in **eight abilities** via a wide range of tools, methods, projects, mindsets, behaviors, artifacts etc. (Carter, 2016). In our workshops we focused on the first three skills.

1. **Navigate Ambiguity**

   This is the ability to recognize and stew in the discomfort of not knowing, and then come up with tactics to emerge out of it when needed. Design is loaded with uncertainty. There are important skills to learn such as being present in the moment, re-framing problems, and finding patterns in information. (Carter, 2016)

2. **Learn from Others (People and Contexts)**

   This ability includes the skills of empathizing with different people, testing new ideas with them and observing and noticing in different places and contexts. Recognizing the opportunity to, and then learning from others is something that happens throughout a design project, both with end users as well as other stakeholders and team members. There is a sensitivity to others that develops with this ability. (Carter, 2016)

3. **Synthesize Information**

   This is the ability to make sense of information and find insight and opportunity within. Data comes from multiple places and has many different forms, both qualitative and quantitative. This ability requires skills in making frameworks, maps and abductive thinking. This ability is co-dependent with navigating ambiguity. (Carter, 2016)

Methods

Course Description:

We designed two different workshops called "Medical Device Design: Identifying Problems Through Observation," and "Medical Device Design: Identifying Problems Through Observation and Hands-On Training". In this paper, we will refer to the first course as observational learning and the second as hands-on training. In this pilot study, 16 interdisciplinary students participated in the first workshop and 14 interdisciplinary students participated in the second workshop. Each workshop lasted two days. We provided our students with background clinical information on maternal hemorrhage and infant resuscitation in advance of the workshop. During the first workshop, students observed clinicians perform procedure simulations and then moved directly into synthesis and brainstorming possible solutions in teams of three (Figure 2). During the second workshop, another group of students followed a similar process, in addition they did hands-on training with neonatologists and OB/GYNs in the simulation lab (Figure 3).

Figure 2. Observational Learning: Students View Maternal Hemorrhage

Figure 3. Experiential Learning: Students Perform Infant Intubation

Due to the brevity of the course, we focused exclusively on the first two phases of design thinking: “Understanding” and “Defining the Problems”.

These workshops were mainly concerned with how we capture our research as designers. We discussed the importance of understanding the “story in,” or, what’s happening now, through focused *observation* (visual learning), *interviews* (auditory learning), and *hands-on training* (tactile learning) as tools for gaining empathy. Afterwards, we synthesized our research in small groups. “Use, Usability and Meaning” was employed as a framework to help students organize their research into a “story out,” or new vision. Where “Use” asks what is the tool or process being used for and “Usability” asks what are the shortcomings of the procedure, the tools or other aspects that could use improvement? We then asked the students to tell us the “Meaning” behind the particular use cases they found. In order to do this, they had to dig deeper into the motivations, culture, and barriers that might exist in the medical environment.

Rather than have students create a “Point of View” (POV) statement *(user + need + insight),* we asked students to state their insight “we were amazed to discover…”. Thereafter a solution space was framed by another statement “it would be game-changing if…” instead of the traditional “How Might We…” statement. A visual aid to describe the idea was then shared. Visual aids, or “prototypes” could be paper models, flow-charts, illustrations, skits or other artifacts the students could make with limited supplies (Figure 3).

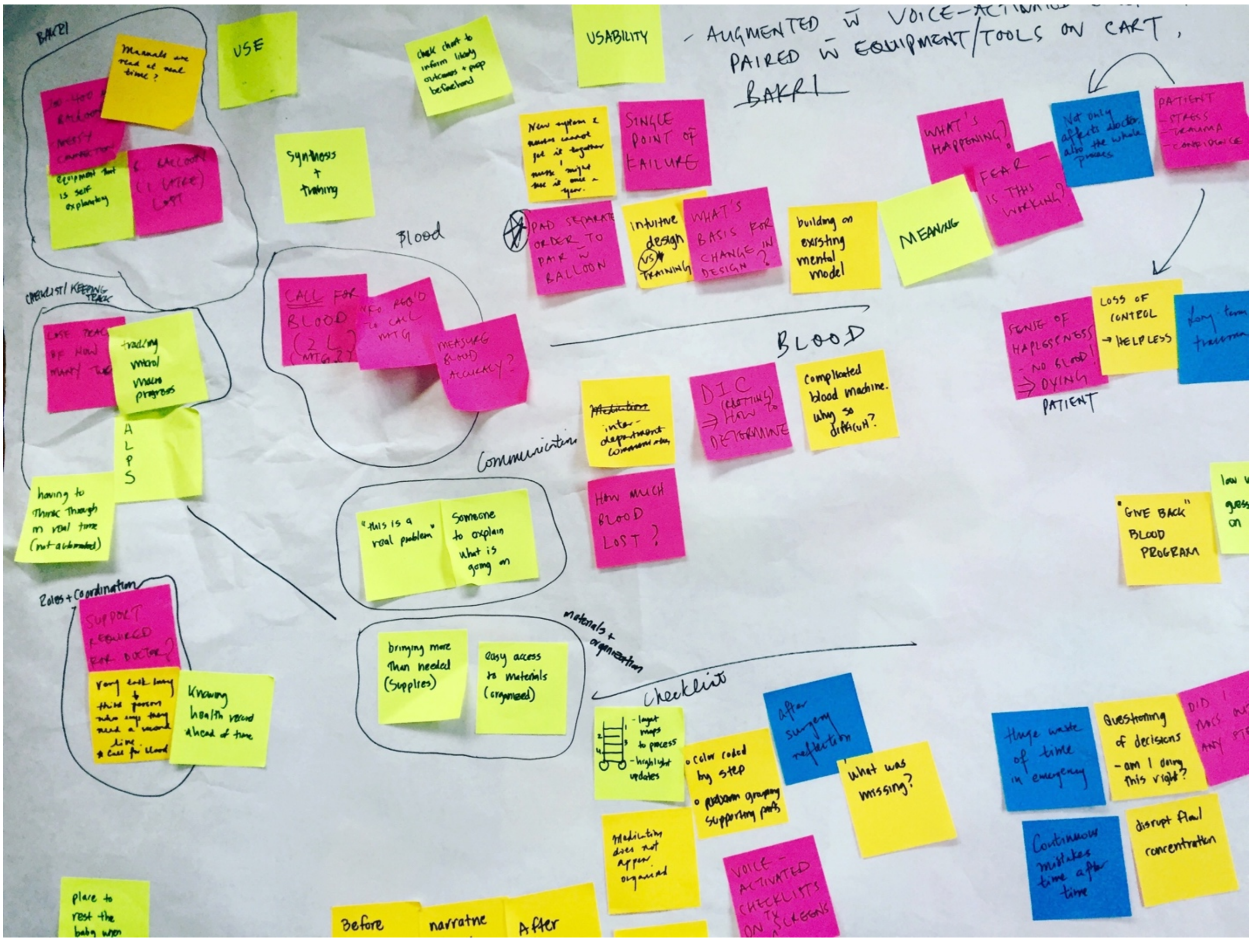

Figure 4. Student Example: Use, Usability, and Meaning

Data Analysis

During both workshops, we measured student comprehension of two different procedures-- infant resuscitation and management of maternal hemorrhage. In both workshops, we asked students to fill out a questionnaire where they listed “important variables” of the procedure before they viewed the simulations and then again after the observational learning or hands-on training. We analyzed the student questionnaire responses using established grounded theory methods. Two researchers independently coded the responses, and then discussed and resolved any differences. Theory was created through the constant comparison method, where new data are constantly compared to previously collected data, relationships between concepts are examined, and categories are continually refined (Foley & Timonen, 2015). Findings were synthesized into major themes.

We then measured the quality of needs identified and solutions presented through a Likert scale survey completed by a panel of industry experts in medicine and product design. Each expert was asked to evaluate each student project on a scale of 1 to 7, with “1” meaning strongly disagree and “7” meaning strongly agree”. The questions were:

1. You heard a memorable story that brings a person/group and their healthcare situation to life.
2. The "We were amazed to discover…" problem is believable and interesting.
3. There is an insight for the problem offered, one that makes sense and reveals unsatisfied or emerging needs.
4. There is an opportunity space (multiple solutions) or possible innovation suggested.

Summary statistics such as mean and standard deviation were calculated. Comparisons between groups were calculated using Student t-test.

Results

Each course consisted of 14-16 undergraduate and graduate students from engineering, design, medicine, business, law, humanities, education, and earth sciences.

The majority of codes fell into five key themes in both groups that students thought were most important both before and after the observational learning or hands-on training. The most prevalent themes were: 1) preparation 2) performance, and 3) communication. The remaining two were equipment design and a safe delivery environment. The comparative thematic data is shown in Figure 5. Analysis codes are shown in Table 1. The prevalence of each code is listed in descending order.

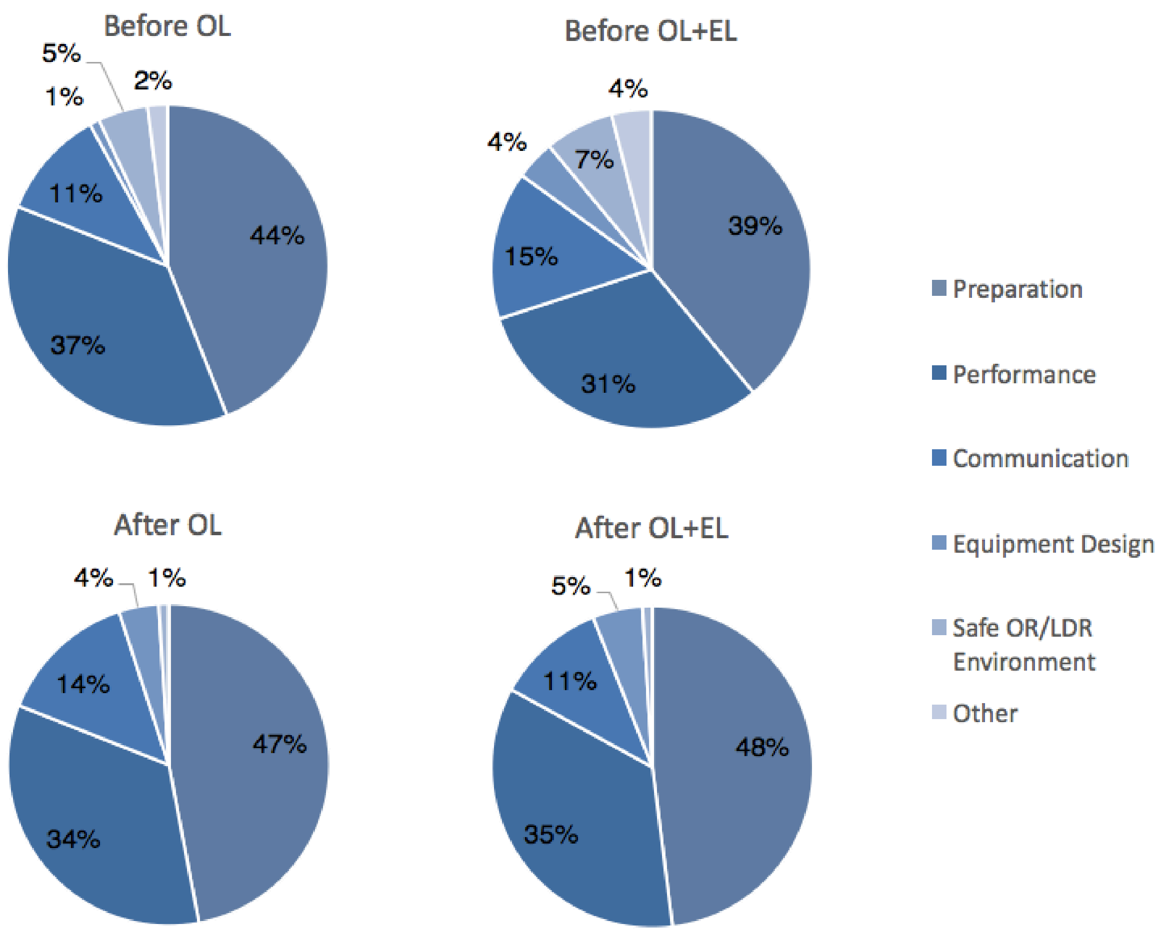

Figure 5. Thematic Comparison: What Students Thought Were Most Important Before and After Each Workshop

Table 1. Analysis Codes

1. Preparation
   - 1a. Availability/Accessibility
     - i. Tools
     - ii. People
   - 1b. Relevant Knowledge
   - 1c. Experience
   - 1d. Training

1f. Mental

1g. General Preparation

2.	Performance

2a. Tools

2b. Timing

2c. Procedure

2d. Diagnosis/Assessment

2e. Follow-up

2f. Do No Harm

2g. Other Performance

3.	Communication

3a. Medical Team Communication

3b. Communication with Patient/Family

4.	Equipment Design/ Efficacy

4a. Appropriate Device Size

4b. Ease of Use

4b. Equipment Material

5.	Safe OR/DR Environment

5a. Sterile Environment

5b. No Obstacles

5c. Calm Environment

Under the theme “Preparation,” the most common code was “Availability of Equipment.” Other codes under this theme were “Relevant Knowledge” and “Experience and Training.” Examples noted by several students included the importance of having the right tools, access to blood, and the option to call for back-up staff. One student noted an important variable was “staff readiness (people, equipment, procedures in place), practiced, alert, proximity, equipment functioning and in a good position.” Another student reported that “anticipation of what might happen - tools preparation (access), skills access (mental prep)” as an important variable.

Under the theme “Performance,” the top three codes were “Tools,” “Timing” and “Diagnosis/Assessment.” We defined “Tools” as clinician’s ability to use the tools correctly. “Timing” was defined as completing a procedure efficiently. One student noted an important variable was “speed of decision making and actions taken.” We defined “Assessment” as identifying when the situation has escalated or changed. For example, one student noted an important variable was “having an RN that can recognize when to call for a pediatrician” and another student noted an important variable was “watching and knowing vitals and at what times to follow-through to next steps.”

The “Communication” theme was split into two codes: “Medical Team Communication” and “Patient/Clinician Communication.” We included visual and verbal cues as well as teamwork and coordination in this category. For communication between patients and clinicians, we defined this code as someone telling the mother and her support people what is going on and their options. Common variables reported by students included communication between the different types of providers (ie: neonatologists, nurses, techs). Some students mentioned allocating responsibility as a major variable (clear role assignments), and maintaining communication throughout the procedure.

The other themes we found were “Equipment Design and Efficacy” and a “Safe Labor and Delivery Environment”. These themes were not as common, but still mentioned by each group. “Equipment Design and Efficacy” included responses such as appropriate size of available devices, ease of instrument use, and appropriate materials for the equipment. For example, one student wrote on the importance of having “a new device that can accommodate babies specifically (keeping in mind their physiology) instead of a scaled down version of what we have for adults.” Another student noted the importance of “knowing how to quickly assemble tools or having easier to use tools.” Under the theme “Safe L&D Environment”, the most common student response was creating and maintaining a sterile environment. Other students noted that it is important that there are “no obstacles when moving close to the infant” and for clinicians to “maintain a calm atmosphere for parents during intubation.”

We did not find a significant difference between the scores given to students in the observational learning versus hands-on training course by industry experts (p=0.44). Comparative and summary statistics are shown in Table 2.

	OL		OL+EL		Comparison	
Question #	Mean	SD	Mean	SD	t-statistic	p-value
1	5.8	1.1	5.9	1.1	0.29	0.77
2	6.0	0.7	6.1	0.8	0.58	0.57
3	6.5	0.4	6.0	0.5	1.82	0.08
4	6.5	1.4	5.9	0.8	0.87	0.38
Overall	6.1	0.8	6.0	0.8	0.78	0.44

Table 2. Summary and Comparative Statistics. SD=standard deviation

Student Examples

An example of systems innovation in the OL+EL workshop was a group that developed "The TACO Truck". "TACO" was an acronym for: "Training Advanced Critical Care Operation". In this project, students imagined a mobile unit for offering smaller hospitals without simulation facilities the opportunity to practice critical care skills in L&D and the neonatal intensive care unit (Figure 6[HCL6]).

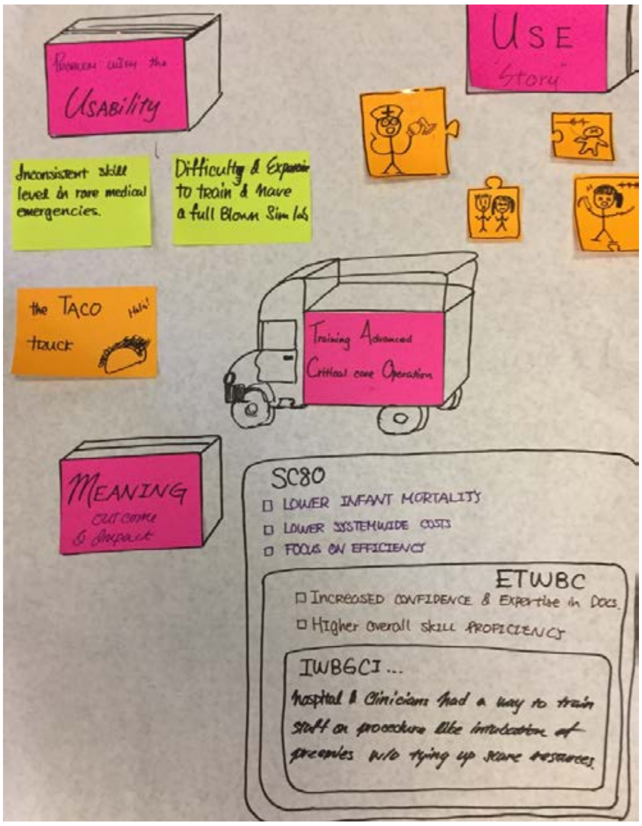

Figure 6. Student Example: Training Advanced Critical Care Operation (TACO) Truck

In contrast, a group in the observational learning workshop focused on the difficulties of infant intubation. They noticed that the clinicians had a difficult time seeing down into the laryngoscope in order to place the breathing tube correctly in a newborn. Even though there are three sizes of laryngoscope depending on the size of the baby one is intubating, the opening is small, so tube placement errors frequently occur (Figure 7). According to an attending neonatologist at Lucile Packard Children's Hospital, and also a co-instructor, 40-60% of intubations actually require a reintubation due to errors in placing the tube. "Intubation is a high-pressure situation, the heart rate is low, they are effectively are not circulating blood and are close to death." With stress level in mind, the group told a new product design story "story out" using an existing laryngoscope and paper model that represented a camera that connects to the device. The camera would allow a neonatologist to clearly see both the trachea (airway) and esophagus clearly while intubating a baby. This camera could also be used more generally for pediatric or adult intubation. The story expanded with the potential for integrating sensors that could give haptic or visual feedback (on the camera) if the tube was placed at the wrong angle, or distance (Figure 8). Although later the group realized that cameras which attach to such devices already exist, the addition of haptic or visual feedback was unique.

Figure 7. Examples of Existing Intubation Equipment

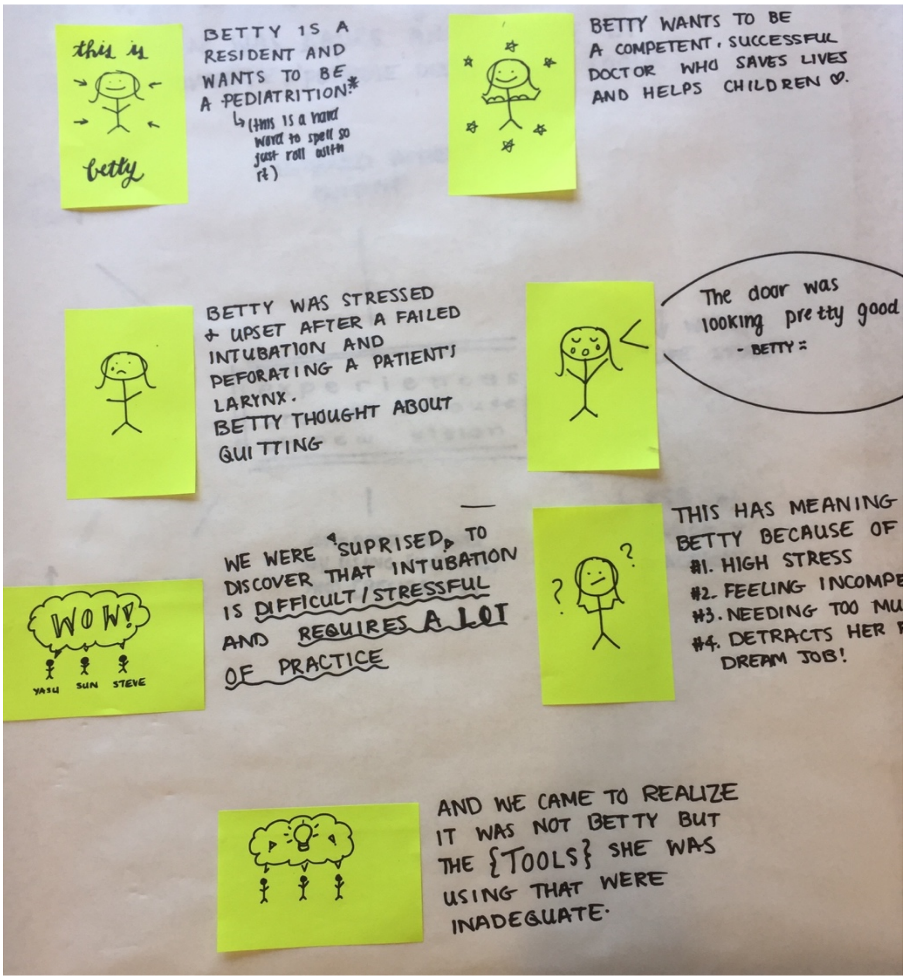

Figure 8. Student Example: Infant Intubation Camera

When a student group in the OL+EL class observed OB nurses using the Bakri Balloon®, they noticed the grimace on the nurse's face after pumping the water into the uterine balloon for several minutes. After experiencing performing the procedure themselves, they learned that the pump system is extremely uncomfortable to use, and set out to design a new handle on the pump in order to improve ergonomic issues associated with this device (Figure 9; Figure 10). The EL strongly influenced the project they wanted to explore.

Figure 9. Students Using Bakri Balloon

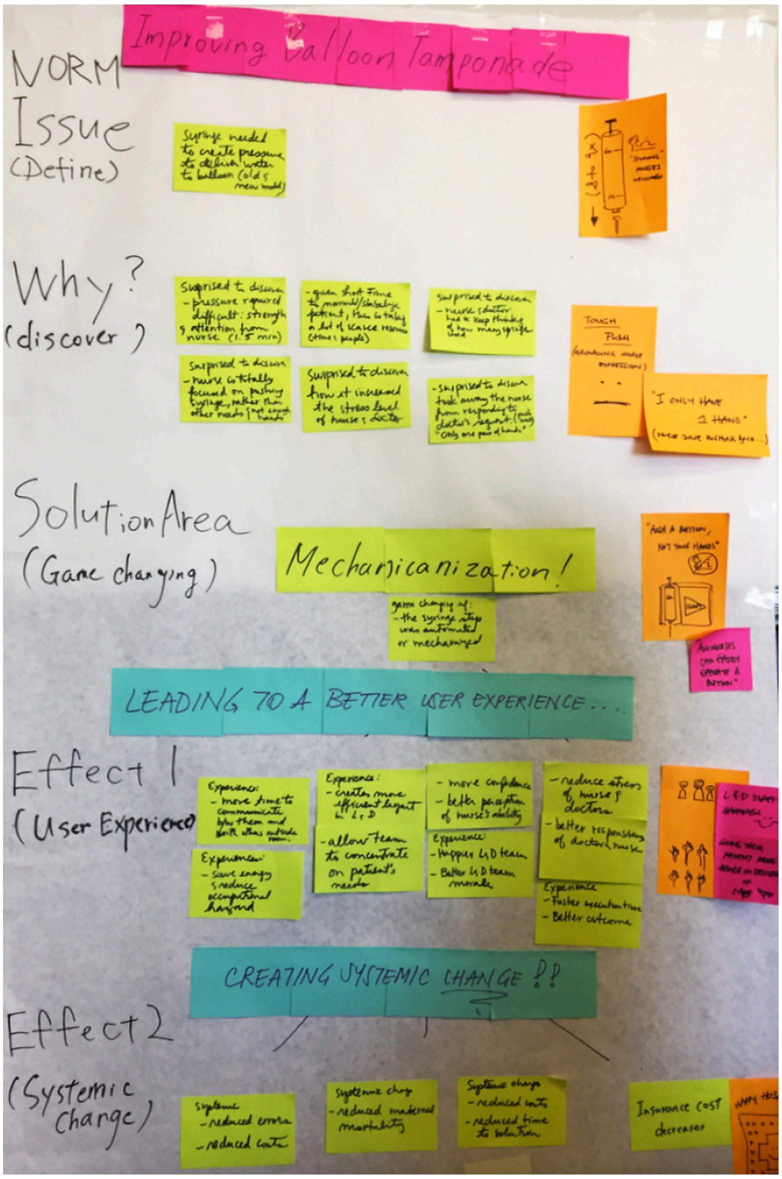

Figure 10. Student Example: Improving Ergonomics of the Bakri Balloon

Blood accessibility during maternal hemorrhage was addressed by a student group in the observational learning workshop. After observing the entire scene during the simulation, they created a list of all the barriers that could potentially delay getting blood to the patient (Figure 11). By creating a timeline of what they saw during the hemorrhage simulation, they were able to tell a new story:

- Suggested points during care when new protocols might be implemented to initiate faster communication between the OR/LDR and the blood bank in the hospital.
- Recommended shorter distances between blood bank and the L&D unit.
- Imagined new tools for quantifying blood loss.

Figure 11. Student Example: Blood Accessibility During Maternal Hemorrhage

Discussion

While innovation may improve a specific procedure or work-flow, the effects may radiate out to the greater system. We asked students in both workshops to share their perceptions of how improving standard practice would not only affect the direct user, but how it might impact the entire healthcare system.

Recognition of emotional drivers may lead to faster adoption of new products, systems or services. During our clinician interviews students asked, “What may be the emotional consequences of bad design?” Physicians indicated that blaming others for bad outcomes, self-consciousness, and feeling incompetent could be triggered by poorly designed equipment. Besides looking for fundamental engineering and human factors issues in existing equipment, designers need to probe how these products are perceived by clinicians. “Work-arounds,” (home-made solutions) are a good indicator that a device or system is subpar, or that something needed simply does not exist.

Observational learning represents a learning method that places observation in the forefront of the learning process, with a key benefit seeming to derive to observational learning from heavy cognitive demands placed on people when directly experiencing a task, as opposed to lighter demands placed on observers (Many & Sims, 1981; Nathan & Kovoor-Misra, 2002). Observational learning affords design students or a professional designer the ability to simultaneously see how current medical devices are being used as well as observe peripheral activities. This includes the use of other devices in tandem, workflow of clinicians and communication. Being able to see “the big picture” may allow the designer to understand various challenges at once thereby leading to a holistic approach to design.

Other studies that compare observational learning and hands on training suggest that complex simulations need to be supported with information regarding the aspects on which students should focus. At the d. School, we deliberately do not give students direction regarding where they should put their focus (Stegmann, Pilz, Siebeck, & Fischer, 2012). Our students were simply provided with background clinical information on maternal hemorrhage and infant resuscitation. The entire point of interdisciplinary human-centered design classes is for students to uncover needs that they see through the lens of their own unique backgrounds.

Because the workshops were brief, students did not have time to master these skills, but were introduced to each skill. In most of the healthcare design classes that we teach, the full quarter format allows students to practice each of these skill sets in order to become more comfortable with the design process. In the past, substantial history and background of whatever subject we were studying: hospital birth, the history of the NICU, etc. would be offered to students. As we continue to teach healthcare design classes and workshops, class time dedicated to background and expert lecturers becomes less substantial. We have found that forcing students to jump right into a complex medical environment, with very little information keeps their perspective fresh, and retains the naïveté that is so important for reframing old problems. In this way, we create an environment that allows students to form their own conclusions before learning other people’s perceptions of a procedure, product or protocol.

Although the quality of the ideas and execution were similar between both the observational learning and hands-on training workshop groups, the instructors noticed that the integration of EL into the second workshop created a higher level of excitement in the class. Most of the students were not from a medical background, so the opportunity to be trained in medical procedures was fascinating and unique. The simulation environment is always impressive for outsiders and the opportunity to interact with attending doctors for both procedures was an unusual privilege. For other instructors teaching medical device design, we would recommend combining both observational learning and hands-on training into their curriculum.

Pilot studies represent a fundamental phase of the research process. The purpose of conducting a pilot study is to examine the feasibility of an approach that is intended to be used in a larger scale study. A pilot study is an initial first step in exploring a novel intervention or an innovative application of an intervention. Yet still, pilot studies carry inherent limitations. The brevity of these workshops may have influenced the outcome of the study, and finally a high level of curiosity and motivation among the student population probably led to above average outcomes in the workshops.

In order to understand the impact of observational learning and hands-on training at a deeper level, both workshops could be expanded into two different full quarter classes that follow the same model, but allow the students to expand their design thinking skills to prototype and test their ideas in the real world. By having the luxury to experience every phase of the design process with more rigor, the data we collect on two full-quarter classes would likely be more comprehensive and reveal differences that could not be measured during a two-day workshop.

The novel intervention for design students was to allow them to experience hands-on training, like medical students, but with a very different end goal in mind. Rather than a goal of mastering the procedure, our design student’s goals were to understand the challenges associated with learning the medical tools abilities and limitations, and the clinician work-flow in order to not only see, *but feel* what kind of design solutions may improve a particular procedure—in this case maternal hemorrhage or infant intubation.

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Pathway to support the adoption of PBL in Open Data education

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Abstract

Governments, public sector institutions and organisations have started releasing and sharing information in the format of open data (OD). The opportunities to create and innovate with OD will continue to grow, and there is an expectation that educational institutions will produce competitive graduates with OD skills. A key question arising from these expectations is how to equip the workforce and students with OD skills. Based on literature from education design and design fields and an empirical analysis of different OD training activities in five European countries, we identified a need to support OD teachers by developing a visual, structured and simple model to guide them through the adaption and implementation of PBL and foster their competences as learning designers, thus the paper proposes an OD–Problem-Based Learning (PBL) pathway model. The pathway model aims to guide educators by structuring the design process of OD training activities and promotes design skills among teachers. The pathway model comprises five main steps: understand, review, design, teach and reflect. Each step provides guidelines on how to plan an OD course.

Key words

learning design, problem based learning, teacher as designer, open data, university training, and vocational education

Introduction

In the past years, governments, public sector institutions and organisations have started releasing and sharing information in the format of open data (OD) to contribute to economic growth and increase transparency. Building on the principles of openness, participation and collaboration, the OD movement works towards increasing access to data and analytic tools that can reduce the need for specialist analysis competences in working with OD (Kitchin, 2014). Furthermore, the movement aims to (1) increase citizen participation in public management to foster transparency and accountability and (2) create new services and products by combining public data with other datasets to foster innovation and creativity (Carreras, Fischer, & van Steenbergen, 2015; European Commission, 2011; Kuk & Davies, 2011). However, fulfilling the potential of OD has faced difficulties getting the public to use the data because most people are unable to collect, process, merge and make sense of it (Hellberg & Hedström, 2015). Other challenges relate to the quality and format of the data and to organisational challenges such as changing the cultural mind-set and establishing collaboration among multiple actors to exploit OD (Carreras et al., 2015).

The opportunity to create and innovate with OD will continue to grow and there is an expectation that educational institutions will produce competitive graduates with OD skills. It is also expected that employees and civil servants will develop those skills. However, it is not yet clear how to equip the workforce and students with OD skills. The present paper is framed within a project that aims to develop and promote OD education and training. The project is called ODEdu: Innovative Open Data Education and Training based on PBL and Learning Analytics (http://odedu-project.eu/). The project aims to establish a Knowledge Alliance between academia, business and the public sector to promote OD education and training. One of the goals of the project is to develop a learning model based on PBL and learning analytics. The assumption of the project is that PBL may be a pedagogical approach that will foster innovation and novel training activities within the OD field. The consortium consists of partners in five European countries (Greece, Malta, the UK, Belgium and Denmark) and local partners from three different sectors: academia, industry and the government.

The European Data Portal report (Carreras et al., 2015) has identified that people working with data should have the necessary skills to not only to understand the data but also communicate the results to the relevant stakeholders, and they therefore need both hard and soft skills. Hard skills refer to domain knowledge, mathematic and statistical knowledge, and technical skills, while soft skills refer to problem solving, storytelling, collaboration, curiosity, communication and creativity (Carreras et al., 2015). The development of those two sets of skills could be linked with a pedagogical discussion about feasible teaching approaches and the teachers' skills to teach OD.

From an initial reading these soft skills seem to align well with what is suggested in the literature, that Problem-Based Learning (PBL) approaches can help students develop. PBL fosters not only development of content knowledge (hard skills) but also soft skills. However, while on the surface it seems that PBL fits well with OD training and education, there is a need to better understand how OD training is currently carried out and what are the pedagogical approaches taken. Therefore, the paper starts from an analysis of the challenges that OD teachers encounter when teaching OD and a review of current international OD teaching activities. Based on the analysis of current OD teaching practice we argue for the relevance of PBL in the context of OD training. However, the literature also shows that the change to PBL is difficult, and therefore drawing on research within educational design and the teacher as designer we develop the OD-PBL pathway model based on design thinking. The aim of the OD-PBL pathway model is to structure the design process of the OD training activities and promote design skills among teachers to adopt PBL in their teaching. The development of the OD-PBL pathway model is the main contribution of the paper.

Open Data teaching practice

This section presents an analysis of how OD training is currently carried out and the challenges that OD teachers encounter. The analysis is based on three different sources. As a first step, a desk study of different OD educational initiatives developed by international institutions was performed to gain insight into the current teaching practice of OD. Next, ODEdu project partners conducted interviews about the challenges and good teaching experiences to map the consortium teaching practice. Third, a workshop provided inputs about effective ways to introduce new OD teachers to the PBL approach.

Desk study of existing OD teaching initiatives

In the desk study, different international initiatives aiming to promote the use of OD were reviewed. A list of six active initiatives were selected to obtain a deeper understanding of their teaching activities: P2PU, Open Nepal, Open Data Day, School of Data, Open Knowledge Foundation and School of Open. The selection was based on references from other actors and we checked the list with one of our ODEdu project partners, Open Data Institute.

Related to the global OD teaching initiatives, we found that the strongest organisation promoting the use of OD is Open Knowledge Foundation, and the three most innovative types of training identified were data expeditions, hackathons and learning circles. The central philosophy of data expeditions is learning by doing, which involves working with real problems, group work and role-play (Radchenko & Sakoyan, 2016). Hackathons, which started in the information technology community, are events where individuals come together to work in an innovative way around a challenge. Zoras (2015) has related hackathons with PBL where an interdisciplinary group of students work on finding a solution to a given problem. Scriven (1984) described the learning circles as a conversation that goes through four phases: exploration (what needs to be learned and why), planning (how the learning is to take place), support (organisation of the selected material) and evaluation (progress of the process and the product).

The review of international OD educational initiatives illustrates that in general, there is little training available for OD and the practice of training OD is a mix between traditional teaching, learning by doing and PBL. The modalities of delivery included face to face, blended learning and online courses. However, none of the organisations have given any concrete pedagogical approaches for their designs.

OD teaching practice within the ODEdu project

An interview study was conducted to understand the teaching practice within the ODEdu consortium. In these interviews, we had the opportunity to focus on the different pedagogical designs of the teaching activities and the successful and challenging experiences of teaching OD. In this way, the interviews supplemented the desk study. Using open and closed questions, the interviewees were asked to give a detailed description of their OD teaching activities (main topic/theme, target group, duration, modes of teaching, teaching goal, learning activities, etc.). The interviews were carried out individually, either in person or via

Skype. Five partners from the ODEdu project conducted interviews for the data collection. Nineteen OD teachers from different sectors were interviewed, representing 25 teaching activities.
The analysis of the interviews reflects that the majority of the teaching and training activities conducted by ODEdu consortium members take only a few hours or a full day. Courses stretching over days, weeks and months are less common – except in university teaching. The predominant form of teaching is face-to-face, but there are also a few examples of online and blended learning.

The analysis focused on identifying successful and challenging experiences related to teaching OD. Three aspects related to successful teaching experiences were identified across the interviews: relevance, hands-on exercises and the importance of being able to benefit from different competences. First, when asked to give examples of successful experiences with teaching OD, some interviewees emphasised that the content of a teaching activity should be relevant to the participant, and they should be able to see the benefits and potentials of working with OD. Further, to ensure relevance to the participants, it is important that the participants have chosen 'their problem' to maintain engagement towards the end-product. For example, one of the interviewees described how – in a course on OD Business Models – she encouraged participants to discuss their experiences and knowledge of OD separately from their understanding of how businesses work. The aim was to contextualise what was being taught and to help them come up with ideas of how to strengthen the value proposition of businesses using OD.

Second, the interviews reflected that hands-on exercises are an important element in teaching OD, e.g. data cleaning, licenses, possibilities and visualisations. It is important that the exercises are not too technical, but that they are relevant to the participants and have a tangible output. For example, a university teacher explained how the most successful teaching activity is the one where students develop their visualisations using Open and Linked data: 'The actual visualization of their work provides them with a sense of accomplishment that motivates them to learn more about the subject of Open Data'.

The third aspect identified in successful teaching experiences is to benefit from different competences in a learning group. Accordingly, to improve end products and learning outcomes, it is beneficial to compose groups with different competences in regards to OD. According to one of the interviews, this was done with success in the hackathon activities.

In terms of the main challenges, despite the variations in teaching aims, methods and audiences, the analysis found similarities between the challenges described by the interviewees. The following five main challenges were identified across the interviews: First, OD is a complex and abstract concept, which at times causes difficulties defining and communicating the practical usefulness and potential added value of OD. Second, as teaching OD is reasonably new, several teachers highlighted the lack of existing learning materials such as relevant and interesting datasets, supporting examples, successful case studies and user-friendly tools for publishing and visualising OD. Third, it is a challenge to fight the impression that OD requires technical skills and to connect the technical side to the everyday practice of the target group. However, OD is associated with technical aspects, and thus the concept becomes tangible when participants have programming skills. Fourth, participants often have diverse knowledge and skills, which poses a challenge in teaching and dissemination. Fifth, hesitation to adopt OD is reflected in the limited willingness to open up data sets and recognise the potential and importance of OD. OD challenges people's mind-sets and previous business models.

Summing up, the interviews showed that most teachers apply traditional teaching methods with limited use of PBL elements. However, the successful teaching experiences described in the interviews support that PBL could be a useful approach to teaching OD. Accordingly, a workshop was initiated to further explore the relevance of PBL in OD teaching.

Workshop on using PBL in OD context

Considerable information exists on teaching by PBL. However, it can be difficult to navigate and implement as a newcomer to PBL. Taking this difficulty into account, a workshop was organised with two PhD students from the open and linked data field, three PBL researchers and two ODEdu project members. All participants were from Aalborg University in Denmark. The workshop was developed around the question, 'How can we help a new teacher coming to Aalborg University to design an OD course using the PBL approach?' The workshop lasted two hours and used materials such as paper, pencils and visual models to facilitate dialogue, communication and interaction among the participants. The workshop was video recorded and transcribed.

The following six themes emerged from the thematic analysis of transcripts from the workshop on taking a PBL approach to teaching OD. The first two themes concern the organisation of a teaching activity, whether it is a hackathon, a semester project work or a one-day workshop. First, it is essential to consider the *time frame* early in the teaching planning process. The focus group participants discussed how the available time influences how complex and open the problem space can be framed, and one of the participants argued that 'the shorter the time, the more you sort of need to frame'. The time frame for the PBL process must thus be aligned with the pedagogical approach.

Second, *collaboration and group work* are central to PBL. When organising and planning the context of an OD teaching activity, the composition of groups should be decided. In line with findings from the interviews, the focus group participants discussed how groups could be composed so that different competences match the complexity of working with OD.

The third issue put forward by the participants was whether *teaching should be guided by available data or by a specific problem*. In the first case, a set of available data sets the outer limit for possible questions raised for that specific data set. In the second case, any question can be raised, but the available data may be insufficient and additional data must be collected.

The teacher should also decide whether the process of working with data or actually solving the problem is what forms the *content of the course*. If the process is the centre of the teaching, specific methods should be applied to solve the problem. However, if the course is focused on the end product, optional methods and approaches can be used throughout the course. The workshop participants illustrate this decision by explaining the importance of learning to navigate towards the problem: ‘So you could tell people “Well, see you here at three o’clock” or “See you here at three o’clock, but you have to take the bus”.

Similarly, the *extent of instructor guidance* should be considered in the course design process. Should the teacher take control of the learning by guidance or should the students take a leap of faith into the problem solving. One participant mentions that the teachers ‘need to decide how much they want to control and how much they want to delegate to the students. I think that is a basic issue, at least to me’ (PBL researcher, workshop).

Finally, the participants mentioned *knowledge about pedagogy*. The participants who were PBL researchers, strongly argued that to design learning activities using PBL, the teacher has to have a sound knowledge of PBL pedagogy.

In summary, a review of current international OD teaching activities and the analysis of the challenges that OD teachers encounter when teaching OD show that (1) most of the current OD teaching practices tend to be traditional and thus lack innovative teaching approaches, (2) there is not a well-defined pedagogical approach to inform the different choices and (3) the successful examples and challenges fit well with the PBL principles. In the workshop, the teacher’s role as a designer became evident. Many variables were identified that a teacher should consider when designing PBL teaching activities and a variety of ways to approach the designing of a learning activity.

Relevance of PBL in the context of OD training

After reviewing OD teaching initiatives and educational practices, this section continues with a theoretical discussion of the relevance of PBL to the practice of OD teaching.

PBL fosters not only development of content knowledge but a wide range of so-called soft skills, such as communication and collaboration, problem solving, decision-making, critical thinking, self-directed learning, leadership and teamwork. The skills are similar to those needed in OD (problem solving, storytelling, collaboration, curiosity, communication and creativity; Carreras et al., 2015) and to the so-called twenty-first century skills, which students should master to succeed in work and life in the twenty-first century (within the category of learning and innovation skills: creativity and innovation, critical thinking and problem solving, and communication and collaboration; P21 Partnership for 21st Century Learning, 2015).

Previous empirical research demonstrates the relevance of PBL as an educational approach, in the general educational practice, but also in specific. Wilder (2015) analysed 10 quantitative studies in the context of secondary education and compared the academic achievement of PBL and traditional teaching. Wilder (2015) showed that seven of those studies acknowledged significantly higher achievement levels among the students using PBL, two of the studies did not indicate any significant differences and one study revealed that the PBL group achieved lower scores. Within the higher education context, researchers have found that PBL has no significant effect on knowledge but has a significant impact on soft skills; furthermore, PBL students have the competence to integrate the knowledge acquired into practice and into different contexts (Capon & Kuhn, 2004; Dochy, Segers, Van den Bossche, & Gijbels, 2003). Within the field of computer science and computer engineering, several studies (Barg et al., 2000; Coto, Mora, & Lykke, 2013; Coto, Mora, Lykke, Vandel, & Jantzen, 2014; Prince & Felder, 2006) have described the implementation of PBL to overcome problems in the field such as a pure technical focus, individual learning, a deductive teaching approach, high percentage of dropout, high failure rates, lack of competences needed by the industry and a lack of intrinsic motivation. Finally, research within the field of open literacy, closely related to the field of OD, argues for the use of PBL as an approach to develop data literacy skills because, combined with real world data, this approach fosters "higher order thinking, connects procedure to practice, and helps bridge the gap between learning facts and acquiring inquiry skills, critical reasoning, argumentation, and communication" (Ridsdale et al., 2015, p. 13).

PBL focuses on integrating theory and practice (Savery, 2006). In this understanding, knowledge and learning are contextual and situated. Participants conduct research, use theory and apply knowledge to solve a problem in a certain context. This contextual and situated quality of PBL is highly relevant to the OD field because OD aims to create new knowledge and applications to solve real-life problems. Accordingly, this aspect of PBL will respond to the need of teachers for a relevance of OD training.

Within PBL, problems are complex, ill-structured, open-ended and authentic to promote students engagement, discussion and argumentation and to stimulate self-directed learning and multidisciplinary solutions (Hmelo-Silver, 2004; Moust, Van Berkel, & Schmidt, 2005). The discussion and debate during the process of problem solving support higher order thinking and promote knowledge sharing and knowledge construction and construction of common explanations (Hmelo-Silver, 2004). The competences developed by PBL fit well with the skills required to work with OD, furthermore, it deals with the teachers' need and challenge about involving different perspectives and different backgrounds. PBL offers the relevant aspects of working with real problems, solving complex problems in multidisciplinary teams, thinking critically and creating relevant contextual knowledge.

In summary, the five core principles of PBL (problem centred, collaborative learning, critical thinking, self-drive and reflection) deals with most of the challenges presented in the OD teaching practices presented in the previous section, and the approach can potentially leverage the successful practices and experiences of teaching OD. The challenges to design OD training using PBL will demand that the teachers re-think how they teach as well how students learn. This process may bring innovation to the teaching practice, as well as innovation in the outcome of the teaching activities (Irons & Thomas, 2015). However, the proposal to adopt PBL to develop OD training is not a simple solution because existing literature shows that pedagogical innovation is a challenge for teachers (Conole, 2013), as well as the adoption of PBL (Ertmer & Simons, 2005). The following section argues that teachers need to be supported in their learning design process. This argument was identified in the workshop, but it is also a request if we aim for innovation in the teaching approach.

Teacher as designer

Designing the learning activity requires teachers to manage a considerable amount of information from many different sources (students, university, pedagogy, experience); thus, the teacher should experiment with the interactions between many elements and hold a constant dialogue between the content and the pedagogy to find a feasible way to design the OD course while applying the PBL approach.

The overall situation is complex because, on the one hand, the teachers are in a changing field that is regularly updated with new technologies, and on the other hand, the teachers can benefit from implementing active learning and student-centred approaches, such as PBL. Such approaches are complex and require teachers to change their ways of thinking and acquire new knowledge about the pedagogical approach.

Ertmer and Simons (2005) argued that most of the novice PBL instructors are likely to encounter difficulties when planning, implementing and assessing PBL, stating that without adequate support, the adoption of PBL methods is likely to be extremely limited. Therefore, there is a need to support teachers with a wide variety of sources that enable them to cope with the diverse challenges. Ertmer and Simons (2005) also argued that teachers need new tools and strategies to support their adoption of new roles and planning of PBL activities, which led us to find a way to support OD teachers' adoption of PBL as part of their teaching practices. Accordingly, we define a profile of a teacher with experience in OD, but a novice in PBL and with the need to become a learning designer.

Recently, educational research communities have highlighted the need to view teachers as designers. Design is often described as an ambiguous, ill-defined problem, which involves many possible solutions (Cross, 2011), several decisions (Aurisicchio, Ahmed, & Wallace, 2007) and questions in the form of deep reasoning questions and generative design questions (Eris, 2003). Within the field of software development, Winograd (1996) defined design as a conscious, creative and communicative process, a dialogue with material and a social activity, which has social consequences and keeps human concerns in the centre.

Beetham and Sharpe (2013) stated that design is relevant to teaching practices because design bridges theory (principled approach) and practice (contextualised and in continue change practice), and they argued that design activities have a high value in the knowledge and digital society. Laurillard (2012) claimed that teaching in line with design professions aims to change and transform the learner's mind; therefore, seeing teaching as a design science will promote the creation of knowledge not only by educational researchers but also teachers (practitioners). Conole (2013) considered that design enables teachers to develop more effective learning environments by supporting teachers to make informed decisions about new technologies and innovative approaches that can respond to the current educational context.

According to Conole (2013), learning design encompasses the process of designing learning experiences and the outcome of the design process. It helps teachers make informed choices regarding learning interventions and it can support teachers to document and share their ideas and products with other teachers.

Principles and challenges of teacher as designers

Reviewing the literature within this field, we identify four common principles that support teachers as designers: (a) the learning designs should be sharable and understandable, (b) the design process should be explicit, (c) teachers' design practice should be community based, and (d) teachers should be able to learn and improve by reflecting on their process and products.
The principle that learning design should be sharable and understandable relates to how teachers should effectively describe teaching ideas so they can be shared with and adapted by other teachers (Dalziel et al., 2016). Regarding the design process, Conole (2013) argued that an explicit design process enables teachers to develop more effective learning environments and helps teachers to end with a more explicit and sharable product. The need to have an explicit design process and understandable and sharable results that are closely related with the principle of working as a community. According to Laurillard (2012), teachers need to build on the work of others, innovate, test, improve and share through a continuous cycle to develop the discipline of design within teaching. Finally, teachers as designers should reflect and create knowledge to improve learning environments and interventions for learners (Conole, 2013; Laurillard, 2012).

However, we identified four main challenges that teachers face when becoming designers for learning. First, the huge amount of information and tools available and the lack of teachers' skills required to use them for teaching and learning is a serious challenge that hinders teachers' abilities to integrate those resources into engaging learning environments (Conole & Wills, 2013; Laurillard, 2012; Mckenney, Kali, Markauskaite, & Voogt, 2015).

A second challenge is the lack of necessary design skills to make informed learning interventions. According to Conole and Wills (2013), teachers lack the design skills needed to create or adapt educational resources to their teaching. Conole (2013) argued that teachers 'do not know how to design and they mainly adopt an implicit approach based on previous experiences and practices' (p. 102). Therefore, there is a need to support and guide teachers to think differently and change their design practice from that of an implicit and belief-based approach to an explicit and design-based approach (Conole, 2013; Conole & Wills, 2013).

The third challenge is the lack of frameworks and structures to support the design activity. Conole (2013) called for a more formal approach to design for learning, which is a 'more systematic, explicit design approach, drawing on empirically derived and validated tools and methods for design' (p. 6). One of the recommendations in this regard is the power of visualisation to provide a means to guide the design process (Conole & Wills, 2013) and the use of design thinking tools such as drawings, prototypes and imagination (Cross, 2011; Lawson, 2005).

As a combination of the previous challenges, the fourth challenge is the gap between novice and expert learning designers. Dalziel et al. (2016) stated that experienced teachers might be able to make judgements about the design process without needing detailed descriptions or information, while novice teachers likely need more guidance. The general design field suggests that novice designers require structure and organising principles, guidance from skilful teachers, exposure to many successful examples to draw on and support from a community (Ahmed, Wallace, & Blessing, 2003; Cross, 2011; Lawson, 2005).

Despite the existence of research work in this field and the increased referral to the teacher as a design professional, this is an incipient field lacking practical and concrete design processes that can guide novice teachers to adopt a new specific pedagogical approach. We thus identified a need to support OD teachers by developing a visual, structured and simple model to guide them through the adaption and implementation of PBL and foster their competences as learning designers.

OD-PBL Pathway

The proposed pathway for OD teachers is developed based on theoretical knowledge of teachers as designers with insights from the empirical work presented above. The proposed pathway is aligned with Conole's (2013, p. 131) proposal of a learning design methodology. The OD-PBL pathway is pragmatic (useful tool for practitioners to address OD educational challenges), theory driven (recognises the complex, messy and diverse field of PBL, but extracts key principles for novice PBL teachers), collaborative (encourages the OD teachers' community to support each other), iterative, adaptive and flexible.

The pathway includes three main elements: (1) a call to approach the teaching activity with a design thinking mind-set, (2) a concrete and visual design process, and (3) a set of proposed methods to support each step in the design process. Figure 1 shows the overall model.

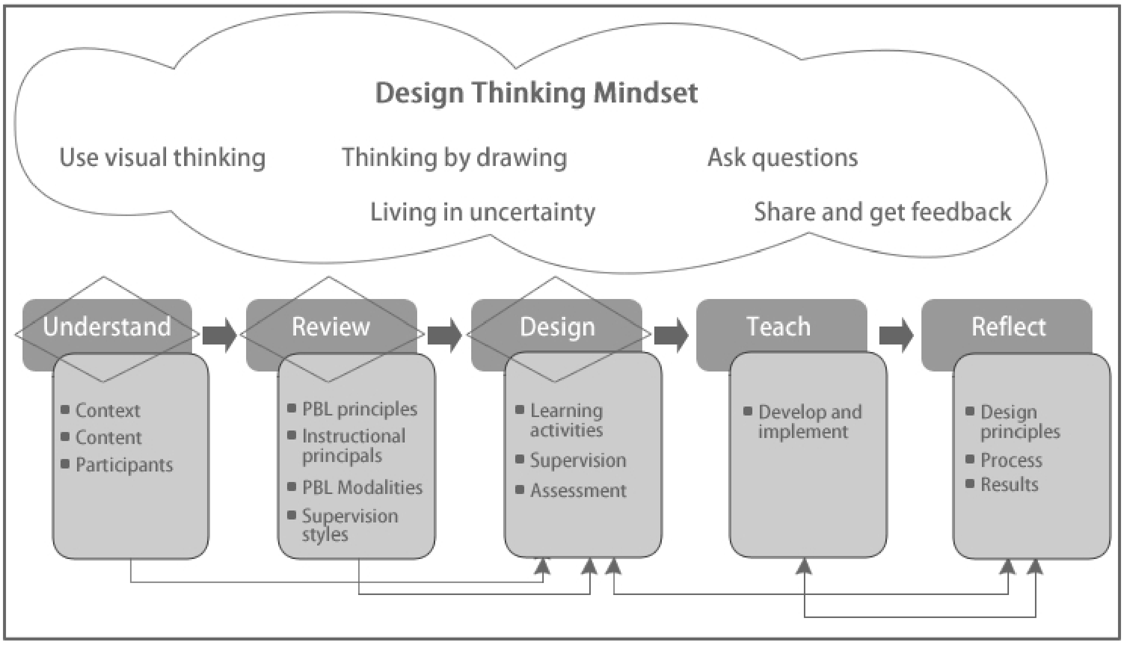

Figure 1: The OD-PBL pathway. A pathway to adopt PBL as teaching approach in OD education.

Design thinking mind-set

Based on the literature and the findings from the interviews and the design workshop, we identified the need to be explicit about the mind-set that teachers should cultivate to innovate their teaching practices by using PBL and information and communication technology (ICT). The OD–PBL pathway (Figure 1) lists five 'designerly' ways of thinking in the cloud at the top that should be explicitly fostered among teachers to enable them to become learning designers.

(1) Use visual thinking: Visualisation is the process of producing ideas or representing data into maps, images and/or stories in two or three dimensions to communicate and discuss that information. As defined by Goldschmidt (1994), 'visual thinking is the production of thought via visual imagery' (p. 161). Imagination is thinking about a situation that is possible but not real at the moment; it requires envisioning the future. Visualisation facilitates the understanding of complex things that are difficult to express with words and can represent complex situations in a page (Roos, 2006).

(2) Thinking by drawing: This is one of the most needed skills that teachers should practice to become learning designers. According to Cross (2011), 'designers need to use sketches, drawings and models of all kinds as a way of exploring problems and solutions together, and of making some progress when faced with the complexity of design' (p. 37). The use of drawings helps to clarify thoughts and the internal mental process as the designer externalises his ideas. Once the ideas are put onto paper, the designer can interact, criticise, discover and create using those internal ideas (Cross, 2011).

(3) Asking questions: Asking questions is a design activity that improves progress. Asking questions is part of the convergent and divergent thinking within the design activity. Eris (2003) referred to two kinds of questions: deep reasoning questions (convergent thinking),

which aims to understand facts, and generative design questions (divergent inquiry), which create possibilities from facts.

(4) Living in the area of uncertainty: The designer should be able to cope with moving on with ambiguous and uncertain proposals for long a time.

(5) Sharing and getting feedback: Different to the teaching activity, design is a social activity rather than an individual activity. Cross (2011) referred to the design process as 'necessarily social and requires the participants to negotiate their differences and construct meaning through direct, and preferably face-to-face, exchange' (p. 31). The teaching activity is quite individual and the recommendation is to attempt to share the design process and the outcomes with others.

The design process model

This study adopted an overall design process (analysis, design, implementation and evaluation) using labels from the field of educational design. The process presented is a linear sequence; however, the process must be understood as an iterative activity that goes back and forth between the steps. We also see this design process in the way that Cross (2011) described it, as the relationship between the problem and the solution. Designers recognise how the two elements interweave and develop together. In this process, the teacher might move on with tentative solutions that may be open and inconclusive for a long time, while remaining in the process of making sense of the problem.

Step 1: Understanding

Phase one involves understanding where the teaching parameters are discussed and defined. This first step supports the designer in knowing the context, content and participants to define the design challenge.

Context: The OD project contains three general contexts where the learning activity could take place: university, private companies or public institutions. Each of these sectors has a set of values, rules, assumptions and characteristics that would influence the design of the learning processes. Furthermore, the context aspect takes into consideration the institution's organisational culture (e.g. explicit and implicit moral values, political and spiritual values etc.). When examining a particular institution, it is important to consider not only the concrete aspects of the physical and virtual environments available for teaching and learning but also the characteristics of the learners and teachers. Within this context, it is important to understand the time available for the design process.

Content: The designer is presented with a set of options regarding the content of the course. The designer has three options: (1) content given by the institutional curriculum, (2) a list of the users' needs, or (3) a set of desired competences to achieve.

Participants: The participants are the most important aspect to consider in step 1 because PBL is a student-centred approach; thus, it is necessary to get to know the participants to respond to their needs, concerns and desires.

The designer should be able to understand the interdependence between the context, the content and the participants to define the learning goals of a specific activity and move to the next step.

Step 2: Review pedagogical principles

Phase two reviews the key PBL concepts and design principles. This step aims to guide the teacher through a more informed design process regarding pedagogy because they need to have clear design principles to start the design phase. Here, the teacher-designer explores two sets of design principles: the meta-principles and the pragmatic principles. The meta-principles are the core of the PBL approach and comprise the following elements: problem-centred, collaborative learning, critical thinking, self-driven learning and reflection. The pragmatic principles are more instructional design-oriented and include activation, demonstration, application, integration, feedback and communication (Margaryan, Bianco, & Littlejohn, 2015). Furthermore, the teacher should get a clear understanding of the different modalities of PBL and the elements that should be aligned. Finally, the teacher should refresh the knowledge about the different ICT tools that can be used in their teaching to achieve the learning goals.

Step 3: Design

This phase is where the core design activity takes place, and we suggest using design materials (paper, post-it, pencil). The teachers should use most of their design skills to create a learning design that responds to the learning goals. In this phase, the designer should decide and design the PBL modality, the problem, the learning activities that support PBL principles and the instructional principals, the assessment, the supervisor role, and check that the overall design aligns with PBL and the learning goals.

The final product of this phase is the ‘course description’ which includes aspects such as the knowledge, skills and competences to acquire, and the schedule, learning activities, assessments, and course literature.

Step 4: Teach

In this phase, the learning activity is implemented. For many courses, mainly in the university context, the design is implemented gradually; therefore, the teacher may begin implementing the actual design as the teaching time progresses. Because of this characteristic, this is an iterative phase because the design is implemented into the real setting and the teacher needs to reflect and modify the design according to the participants’ responses and the context.

Step 5: Reflect

This step aims to develop teachers’ reflective practice. The goal is that teachers reflect on their design and the outcome of the implementation (teaching) to create a culture of continuous learning. The teachers should critically reflect on the PBL approach, the activities implemented, the assessment and the students’ responses. Teachers should also evaluate the achievement of the learning goals stabilised in step 1. This reflection step is part of ‘learning how to learn’ and being able to communicate the learned lessons to the OD community.

Proposed methods

A variety of design methods exist that can be used in the different design process steps. Table 1 proposes some relevant methods for each step in the OD-PBL pathway including a brief description of the methods and how they could be used. Table 1 also includes a citation for each method so that readers can explore the different methods further.

Table 1

Proposed Methods for the Design Process

Step	Method	Description	References
Understanding	Business origami	This method creates a map of the different people, artefacts, environments and technologies that form a system, in this case the context of the OD.	Martin & Hanington Bruce, 2012, pp. 24–25
	Concept Map	This is a visual tool that can help to generate ideas and identify the key concepts and skills from the teaching activity. The tool helps to define the relationship between the course elements and organise the course content.	McDaniel, Roth, & Miller, 2005
	Empathy map	This method provides a good understanding of the person for whom the teacher is designing and will help to develop empathy. This tool can be used to determine the participants' needs.	Ingle, 2013
Review Pedagogical Principles	Inspiration cards	These are cards on which an image, a title and a reference are printed. We recommend creating inspirational cards for PBL principles, instructional principles, modalities of PBL and supervision styles with PBL.	Halskov & Dalsgård, 2006
Design	Brainstorming	This method aims to generate as many ideas as possible about learning activities to support PBL principles, instructional principles and assessment activities.	(Hyerle, 2009)

	Card Sorting	This is used to organise information into categories and provide a structure. Using the concept cards from the previous phase and the ideas generated in the brainstorming activities, the teacher sorts out the activities under the different principles.	Wood & Wood, 2008
	Learner journey map	A customer journey map is a combination of visualisation and storytelling that represents the process that a person goes through to accomplish a goal. Here, the teacher could create a 'learner journey map' to guide the participants from the current state to the desired state.	Kaplan, 2016
	Check list	This is a kind of rubric that the teachers develop to check the design against the design principles and the learning objectives. This checklist may have questions such as 'What kind of PBL am I applying?' 'Is this problem related to real workplace problems?'	
Teach	Diary studies	For the two last steps, we propose the same method. During the teaching step, the method aims to collect information from participants and/or teacher over time. They can add information about their thoughts, feelings, behaviours, etc. The teacher can use the tool to keep a record of their teaching activities as they are implemented over time.	(Martin & Hanington Bruce, 2012, pp. 66–67)
Reflection	Diary studies	In the second part, the teachers analyse the information collected during the previous step. Here, the method is use as meta-reflection technique that aims to foster self-awareness, thinking, analysis and learning.	(Leitch & Day, 2000)

Conclusions

The paper investigates the current OD teaching practice and found that the practice is guided by a traditional teaching approach (lecture-based). We argue that PBL is a potential pedagogy for teaching OD; however, the teachers would need some kind of scaffolding when adopting this approach for the first time. We thus propose a concrete design process and recommended some design methods to support novice teachers in their design of OD teaching activities.

Pedagogical innovation can be quite demanding, the process and outcomes of the first experience are relevant for continuing the process. The OD-PBL Pathway helps teachers who are new to the fields of design and PBL to develop their expertise.

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23.2

Review of Curriculum Development for University-Industry Collaborations with a Comparative Analysis on Master of Industrial Product Design Education

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Abstract

University-industry collaboration (UIC) provides not only effective training for students but also knowledge production in universities for industry to contribute to the economy (Bektaş & Tayauova, 2013). The paper proposes to analyse reasons for deficiencies in UIC with a comparative analysis of the curriculum of the industrial design (ID) department of Izmir Institute of Technology (IZTECH) and Linnaeus University (LNU), and taking feedback from industry. As a comparative analysis of curriculum, ID programmes in IZTECH and LNU were examined to understand differences and similarities. To develop UIC for IZTECH, LNU was accepted as an example, and then the two institutions were compared according to each curriculum. For comparison of ID courses, the taxonomy method in the National Association of Schools of Art and Design (NASAD) Handbook 2014-2015 was used. There are three categories for design courses, which are professional design practice (PDP), design studies (DS), and design thinking (DT). Within the scope of curriculum development for university-industry collaboration, feedback was taken from companies that have a design department or are an employer of new ID graduates. For this purpose, surveys were sent to different companies. As a result of curriculum analysis and a survey with industry, courses that need to be developed belong to PDP and DT groups, which are more practice and teamwork based. A solution can be adding new courses to curriculum that contain more teamwork and innovative and collaborative activities. Also, content of existing courses can be developed on DT characteristics.

Key words

Industrial product design education; curriculum; master's degree programme; comparative analysis; university-industry collaboration.

1 Introduction

University-industry collaborations (UIC) are increasingly significant to make contributions to economy and society. The mutual relationship can generate knowledge used in production to achieve efficiency in economy and innovation and in this way firms gain a significant competitive advantage in world markets. University-industry collaboration also provides the following benefits regarding learning effectiveness: supporting instructors to update their knowledge; providing a basis for their scientific research; carrying out research to develop fundamental sciences; promoting scientific research by publications and students training as well (Qın, Mkhıtaryan & Bhuıyan, 2017).

Interaction can take a variety of forms, including both direct and indirect mechanisms (Guenther & Wagner, 2008), recently being labelled as ‘academic engagement’ (Perkmann et al., 2013). From the 1980s, UIC has intensified and therefore received growing attention from researchers, policy-makers and practitioners (Etzkowitz, 1998). Government initiatives and changes in the institutional framework have facilitated cooperation (van Looy, Debackere & Andries, 2003; Guenther & Wagner, 2008). However, there is still a gap between the knowledge produced by university researchers and what is used in practice (Siegel, Waldman & Link, 2003). Indeed, a great amount of knowledge created in academia does not come to be applied and consequently create value (Sedlacek, 2013). Given this situation, the literature has progressively dealt with the phenomenon of UIC (Barbolla & Corredera, 2009; Gulbrandsen, Mowery & Feldman, 2011), taking different perspectives, which vary significantly according to the mechanisms/interaction channels, and the units of analysis considered. Since people are considered as the universal drivers to ensure successful UIC (Plewa et al., 2013), most research has focused on the individuals acting in the field (Franco & Haase, 2015).

Firms collaborate with universities mostly to access and develop interdisciplinary scientific capabilities to solve complex industry problems and to support product development, but also to access public sponsorship. Firms may also collaborate with universities to conduct exploratory, non-targeted research to generate ideas, build technological options and search for new products, technologies and markets, and to get access to skilled labour, especially qualified engineers (Meyer-Krahmer & Schmoch 1998; Lee 1996, 2000; Feller, Ailes & Roessner, 2002; Carayol 2003; Lam 2005; Balconi & Laboranti 2006; Arza 2010; Subramanian, Lim & Sohc, 2013).

University researchers are mostly motivated to collaborate with firms to try out practical applications of their theory and research, and to advance and complement their research agendas (Lee 1996, 2000; Perkmann & Walsh 2009; D'Este & Perkmann 2011). On the other hand, they may be motivated by the need to get additional funding and resources to facilitate their research and finance graduate students and the purchase of laboratory equipment, as well as to establish a foundation for future research and collaboration opportunities (Lee 2000; Lam, 2011; Freitas & Verspagen 2017).

Innovation experts have investigated UIC performance of firms (Agrawal & Henderson, 2002; Cohen, Florida, Randazzese & Walsh, 1998; Cohen, Nelson & Walsh, 2002; Shane, 2002; Santoro & Chakrabarti (2002)). They attempted to analyse the modes through which knowledge flows from universities to industry. Nonetheless, there is no universally accepted classification of university and industry collaborations (Røed, 2000). Also, there is little consensus regarding the most effective mode of university– industry collaboration has been achieved (Bekkers & Freitas, 2008; Eun, 2009).

The collaboration modes include, but are not limited to, the use of scientific publications, technology licensing, human mobility (personnel exchange, etc.), joint or collaborative R&D, contracted out or commissioned R&D, consultancy or technical guidance, incubation of start-ups, and informal collaboration. The interaction can take place between individual researchers in both a university and a company or between a company and a university (Agrawal & Henderson, 2002; Bekkers & Freitas, 2008; D'Este, Nesta & Patel., 2005 Eun, 2009; Iqbal, Khan, Iqbal & Senin, 2011; Joseph, 2009; Landry, Amara & Ouimet, 2005; Meyer-Krahmer & Schmoch, 1998; Rast, Khabiri & Senin, 2012; Pittayasophon, 2016)

In industry, companies can take many advantages of university collaborations in terms of regular activities, innovation and new design. Moreover, universities also turn their theoretical knowledge to practical. UIC is established on the transfer of knowledge and technology between them. UIC refers to the interaction between any parts of the higher educational system and industry aiming mainly to encourage knowledge and technology exchange (Bekkers & Freitas, 2008; Siegel Waldman & Link, 2003; Maietta, 2015; Scandura, 2016. UIC has been widely perceived as a promising tool for enhancing organizational capacity in open innovation — where an organization employs external networks in developing innovation and knowledge (Dess & Shaw, 2001), as a complementary option to traditional internal R&D (Coombs, Harvey & Tether, 2003) (Ankrah & Al-Tabbaa, 2015).

The involvement of practice in design education also draws the borders between education and industry. Although the various applications of relations with industry in education have been widely discussed in the literature, (Boyarski, 1998; Çırpanlı and Er, 2006; Erkarslan, 1998, 2007, Erkarslan and Imamogulları, 2010; Erkarslan, Kaya & Dilek, 2011; Evyapan, Korkut & Hasdoğan, 2005) many critical questions, such as whether design education should directly respond to the needs of industry, still remain as unanswered. Besides, policies and strategies in order to increase the intersections between education and industry is still a vital discussion in our field. Design educators and professionals are always concerned with the issue of industrial designers' competencies. However, the quality of ID graduates is not generally regarded to be at the level expected by employers (Kaufmann, 1998), and there seems to be a gap between what students learn at school and what they are required to do in practice after graduation (Ball, 2002; Yeh, 2003; Yang, You & Chen, 2005; Erkarslan, 2013).

2 Literature Review

The lack of innovative education based on industry is a problem that needs to be overcome. Projects conducted within the framework of university and industry cooperation generally fail to come into being, leaving prospective applicants no opportunities. The rate of creation of state-of-the-art technology products was quite low in the joint studies conducted by the companies and academic researchers within the technology parks that enable cooperation between industry and universities (Kiper, 2010). The academic staff of that university designs the curricula of degree programmes within a university. It is a fundamental role of academia. Those degree programmes that lead to a license to practice will also be subject to professional body accreditation, reducing the number of elective dimensions that can be introduced by the university. Although these requirements may be seen as limiting the freedom of employers to further influence the curriculum, experience indicates that there is sufficient common ground between employer needs, quality assurance benchmarks and professional body requirements for there to be little reason why employer needs are not integrated within the process of degree programme design. The level of engagement is clearly at the discretion of the university and occurs at variety of levels of prescription. Many universities operate employers' advisory groups, often at departmental level. These groups may act as 'critical friends', monitoring the activities and development of the department; others act as industry advisors in research fields and in curriculum design. This is a demonstration of business– university collaboration that is often invisible outside a university department. In terms of future employment prospects, the existence of such a group is of legitimate interest to students. Universities that work with employers through industry advisory groups should consider including the existence of such a group, its membership and its influence, within the university's enterprise strategy and within the material that it provides to applicants and students (Wilson 2012).

When both university and industry's expectations coincide with each other, then the resulting UIC is better and easier. Responsibilities and expectations of universities can be defined as providing education, renewing their scholars, contributing to development of science and publishing their results, supporting their scholars for research and academic studies. In terms of industry, the responsibilities can be defined as technological knowledge being satisfied for market, production of solutions for industrialist's problems about manufacturing and supporting manufacturing, development of product quality, and manufacturing more standardized product. Ankrah and Al-Tabbaa (2015) explained that motivations of universities and industries can be examined under six topics; necessity, reciprocity, efficiency, stability, legitimacy, and asymmetry. Necessity is the same definition for both as a motivation, which is being responsible to policies of government and other strategic institutional. Reciprocity can be explained that universities can reach facilities and equipment in companies, when the companies can access to students for summer internship or part-time job opportunities. Thanks to UIC, new graduates find employment opportunities in companies, and industries hire faculty members for consultation. Efficiency is the third motivation for both university and industry. Universities can access funding for their research and further studies, obtain patents and be gained personal finance for academics. Furthermore, companies commercialize university-based technologies and turn them profit. When foreign technology is wanted to be used, companies should take license for it. However, thanks to patents, which are produced by universities, companies do not need to exploit foreign technology, and it is much easier and cheaper. Another saving in term of economics for companies is tax exemptions and grants. Moreover, companies increase their technological capacity and take better place in competitive markets thanks to UIC projects; they also develop their human capital with educated new graduates according to their need. Stability is the motivation, which has the largest amount of results for not only universities but also companies that start growing with new knowledge that is produced by UIC, as a result of UIC they shift in knowledge based economy. Universities take opportunities to discover new knowledge, test them and publish more papers, while companies make their business grow, access new knowledge and technology. Students can find solutions to practical problems and applied technologies of companies, which do not need in house R&D thanks to UIC. Legitimacy motivates not only universities to contribute regional or national economy, service to the industries, increase academics and their achievements' recognition, but also companies to enhance to their corporate image. As a last motivation, asymmetry supports companies to continue controlling patented technologies (Ankrah & Al- Tabbaa, 2015).

UIC has several results (Wilson, 2012, p.41-42):

- Collaboration between university and industry is resulted with progression at many level and exchange of knowledge.
- As a result of collaboration projects, companies have opportunity to find worker candidates who are new graduates, but have knowledge about sector and companies works.
- Students have opportunity to use their theoretical knowledge into practical experience.
- The companies get more theoretical knowledge, and universities can make them expert on any new concept.
- Like businesses, universities thrive on competition; competition has been a driver of performance and efficiency.
- In order to enhance graduate skills levels and ensure a smooth and effective transition between university and business environments, there is a need to increase opportunities for students to acquire relevant work experience during their studies. Sandwich degree programmes, internships and work ‑ based programmes all have roles to play in achieving this.
- Strategies to ensure the development and recording of students’ employability, enterprise and entrepreneurial skills should be implemented by universities in the context of the university’s mission and promoted through its public literature to inform student choice.
- Networking between universities and the business community is a critical component of an efficient innovation ecosystem.

3 Method

3.1. Purpose of Study

The paper analyses the reasons of deficiencies in UIC with a comparative analysis of the curriculum of industrial design department, Izmir Institute of Technology (IZTECH) and Linnaeus University (LNU), and taking feedback from industry. The early phase of the research was realized at LNU-Sweden between September and December 2012 with the support of the Turkish Higher Education

Council Grant. After the analysis on curriculum and industry, the main aim is to develop an efficient curriculum for UIC.

UIC contributes to the economic success of manufacturing organisations, because companies' success in their R&D activities also support their success in marketing, design and manufacturing together (Kotler, 2000; Bruce & Bessant, 2002). Universities and companies have different missions and cultures. However, UIC provides that they bring their problems and difficulties, and when these are solved, both side of UIC gain (Lambert, 2003). UIC contributes to design students training in terms of innovation, identifying problems, producing solutions, working in teams, and coordinating team activities (Spellmeyer & Weller, 2003).

In the view of this information, the importance of UIC can be understood for design students. Thus, improvement of UIC in IZTECH industrial design department the purpose. For this purpose, two methods were used. The first method was the comparative analysis of IZTECH and LNU, and second was to take feedback from the design departments of companies.

One of the reasons to choose LNU for comparative analysis is that both universities have an engineering and architecture based industrial design education tradition. Education is in English at both universities. Moreover, collaboration between LNU and IKEA is the multidisciplinary and collaborative project example that includes research and education about life at home. In this project, business administration, industrial design, engineering and wood technologies researchers worked together. LNU has significant importance for IKEA in terms of employable educated human source, experts and producing results of research. The Bridge Program, which is the name of UIC between LNU and IKEA, determines the education programme in economics, technology, and design departments.

3.2 Comparative Analysis

In this section, curriculums of industrial design departments at IZTECH and LNU are analysed according to NASAD. The aim is to identify similarities and differences between two industrial design programmes, so deficiencies and strengths for UIC in IYTE can be defined after the analysis.

According to NASAD Handbook 2014, practice, study and action are three area of design, and each institution aims to give design education with one or more focusing area of the three. Their focus determines the aims, programme details, levels of engagement, and requirement of resources for success. The courses of the industrial design departments are divided into three subjects: professional design practice (PDP), design studies (DS) and design thinking (DT).

PDP courses aim to develop skills, knowledge and inclinations to design communication, products, environments and services for today and the future. DS courses contain research and critical analysis about how design affects people, their activities, and places. They also study the effects of design on physical, cognitive, social, cultural, technological, and economic aspects of context.

Content of DT courses are process oriented like visualisation, prototyping, etc. and problems of these subjects being solved (NASAD Handbook 2014, 2015).

In Table 1, courses of industrial design departments in LNU and IZTECH are divided into categories of PDP, DS and DT according to their course content. The table also contains information about credits and if courses are mandatory or elective. Courses under the PDP category teach basic skills such as computer aided design, basic material and manufacturing technologies, and presentation. In addition to PDP characteristic, DT characteristics make courses more advanced, like concept development or problem analysis and solving.

University	Courses	Credit	Category	Mandatory/ Elective
LNU	Local Innovation	22,5	PDP+DS+DT	M
	Methods at work	7,5	DS	M
	Innovation for Global Impact	22,5	PDP+DT	M
	Action Research and Interactive Methods	7,5	PDP+DS	M
	Material Culture and practices	7,5	PDP+DS	E
	Philosophy of Science with emphasis on Design	7,5	DS	E
	Methods for exploration	7,5	DS	E
	Articulation	4,5	PDP	E
	Seminar Series 1	3	DS	E
	Human Centred Design, processes, methodology	7,5	PDP+DT	E
	Design, advanced study 1	7,5	PDP+DT	E
	Design, advanced study 2	7,5	PDP+DT	E
	Design theory, advanced study	4,5	DS+DT	E
	Seminar Series 2	3	DS	E
	Co-operative design work, methodology, deepened studies	7,5	PDP+DS+DT	E
	Design in practice advanced study 1	7,5	PDP+DT	E
	Design advanced study 1	7,5	PDP+DT	E
	Design work advanced studies project	12	PDP+DT	E
	Seminar series 3	3	DS	E

	Degree project	30	PDP+DS+DT	M
IZTECH	Industrial Design Studio	8	PDP+DT	M
	Research Methods in ID	6	PDP+DS	M
	Advanced Product Development	8	PDP+DT	M
	Seminar	6	DS	M
	Consumption Trends and Material Culture	8	DS	E
	Evolution of Communication Tools	8	DS	E
	Evolution at Design	8	DS	E
	Material Science and Manufacturing Technologies	8	PDP	E
	Design Management	8	PDP+DT	E
	Ergonomics and Human Factor in Design	8	PDP	E
	Design Engineering	8	PDP	E
	Communication Design	8	DS	E
	Semiotics in Design	8	DS	E
	Sustainable Design	8	DS	E
	Product Innovation	8	PDP+DT	E
	Philosophical Context of Design Research	8	DS	E
	Fashion Concept in Design	8	DS	E
	Industrial and Graphic Photography	8	PDP	E
	Cinema and Design	8	DS	E
	Packaging Design	8	PDP+DT	E
	Furniture Design	8	PDP+DT	E
	Computer aided product design 1	8	PDP	E
	Computer aided product design 2	8	PDP	E
	New Product Design	8	DS+DT	E
	Time and Space Design in Transnational Cinema	8	DS	E
	Special Topics in Industrial Design	8	DS	E
	Special Studies	4	PDP+DS	M

	Special Topics	4	PDP+DS	M
	Master Thesis	26	PDP+DS+DT	M

Table 1. Taxonomy of industrial design courses at LNU and IZTECH according to NASAD Handbook 2014.

In the data analysis section, there are two different analyses, which are separate characteristics and general characteristics. In separate characteristic method, each courses characteristics are examined, then these are observed; PDP, DS, DT, PDP+DS, PDP+DT, and PDP+DT+DS. This method shows that some courses contain one than more characteristics. In graphs of the general characteristic method, the total number of each course which has any characteristics, is shown as PDP, DS and DT.

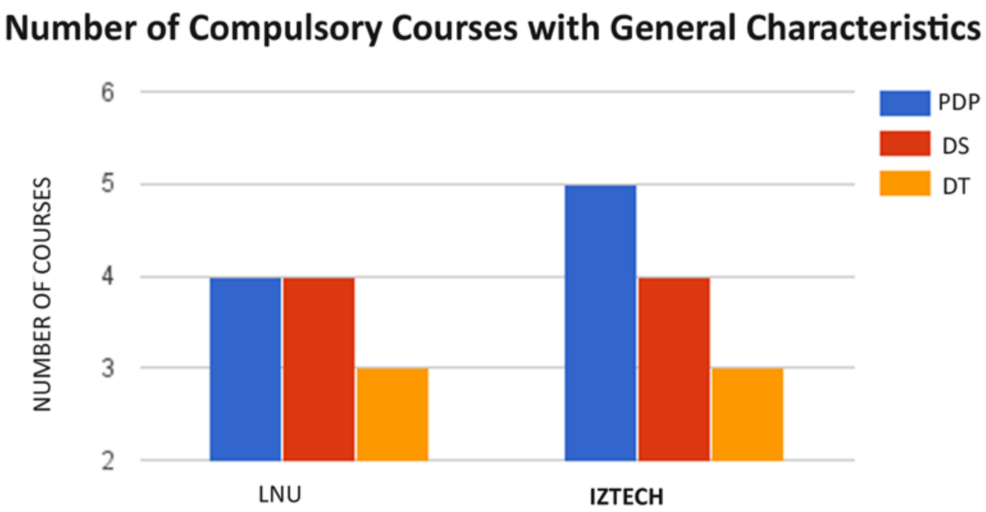


Figure 2: Number of compulsory courses in industrial design department at LNU and IZTECH and their general characteristics.

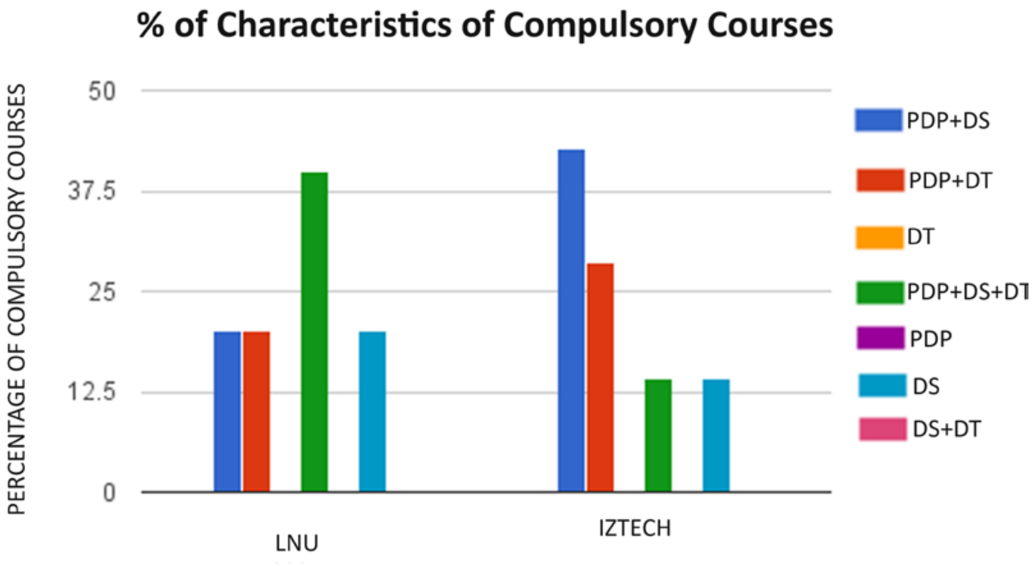


Figure 2 Percentage of distribution of characteristics into compulsory courses in industrial design department at LNU and IZTECH.

When data in the Table 1 were analysed, the number of compulsory courses of industrial design departments at LNU and IZTECH and their characteristic can be seen in Figure 2 which shows IYTE has more PDP characteristic courses, but there is no other difference in terms of general characteristics. However, when each course is examined according to their individual characteristics in Figure 2, LNU offers more PDP+DS+DT characteristic courses than IZTECH. This type of courses teaches not only basic skills but also working with teams, developing concepts and analysing and solving problems. As seen Figure 3, both programmes offer almost the same number of elective courses, but courses at LNU have equal distribution in contrast to courses at IZTECH which have more DS characteristic elective courses. All elective courses are examined separately; IZTECH has some missing characteristics, while LNU offers courses in more various characteristics as seen Figure 4. As a result of the first method, differences and similarities were determined between curriculum of industrial design programmes at IZTECH and LNU. The most noticeable difference between the two programmes is distribution of characteristics in elective courses. The number of PDP+DS+DT courses at IZTECH is less than LNU. Moreover, LNU offers elective courses in each characteristic in contrast to IZTECH.

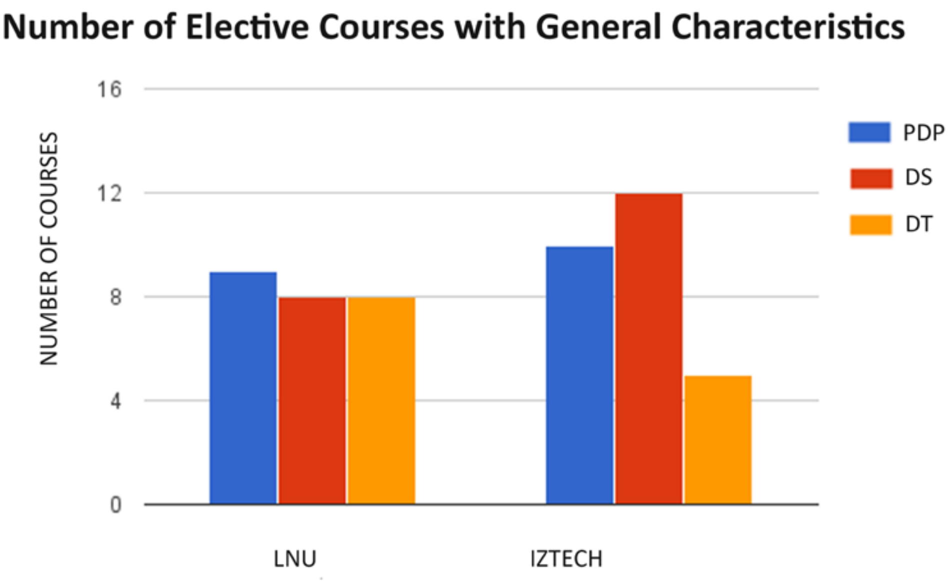


Figure 3. Number of elective courses in industrial design department at LNU and IZTECH and their general characteristics.

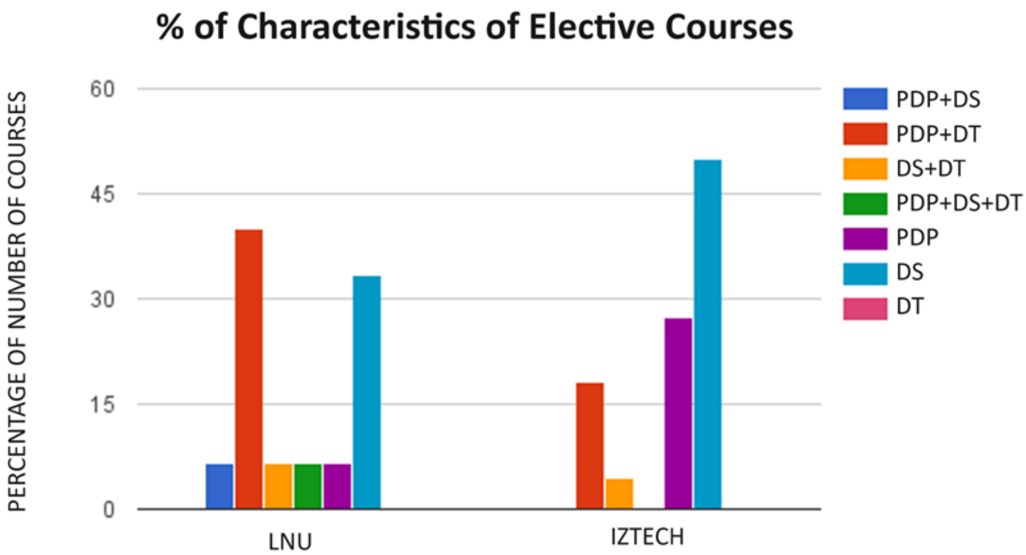


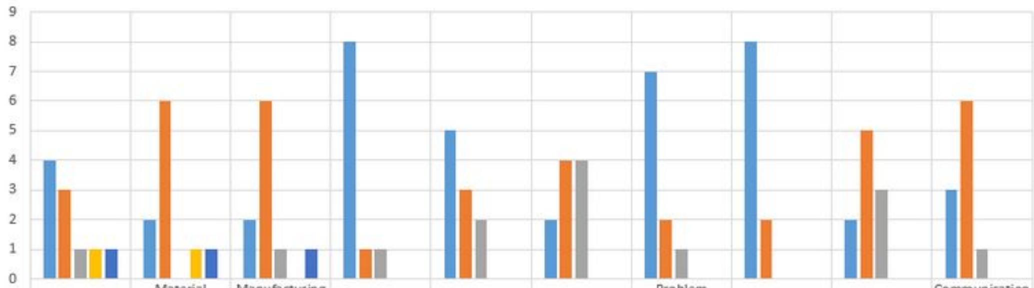
Figure 4. Percentage of distribution of characteristics into elective courses in industrial design department at LNU and IZTECH.

3.3 Feedback Session with Industry

A second method was taking feedback from industrial design departments of companies or individual designers that had opportunity to work with new graduate of industrial design departments. For this purpose, a survey, which had 11 questions, was sent to design department managers or industrial designers. The first 4 questions aim to learn who they are, and how much experience they have, the next 6 questions are about the situation of new graduates and what companies or employers' expect from them, and the final question asks additional opinions of participants.

The feedback session was designed as a small-scale survey (Owen, Fox & Bird, 2015), which is used where researchers have limited resources that can cause limitation in terms of the size and scope in the survey. Small-scale surveys can be examples for student's projects or dissertations in a social science area (Punch, 2003). When participants are determined, a variety of department and business segments are given importance, because nowadays graduates of industrial design departments are not only working for manufacturing industries, but also working for interaction or user experience design projects. There are 10 participants who answered 11 of the questions.

The second part of the survey includes questions to learn current situation of new graduates and expectations of companies from them. In this part, the fourth question aims to learn expectations of companies from new graduate industrial designers in terms of skills and knowledge. Answers of 8 participants show that the most important two skills are teamwork and concept development (Figure 5).



	CAD software knowledge	Material science knowledge	Manufacturing technologies knowledge	Tendency for team work	Ability of presentation	Marketing knowledge	Problem analyzing and solving	Concept Development	Project Management	Communication with other department
Definitely Required	4	2	2	8	5	2	7	8	2	3
Required	3	6	6	1	3	4	2	2	5	6
Not a must	1	0	1	1	2	4	1	0	3	1
Unrequired	1	1	0	0	0	0	0	0	0	0
Definitely unrequired	1	1	1	0	0	0	0	0	0	0

Figure 5. Answers of the question 4 which is about expectations from new graduates from industrial design departments

The next question is "In which level new graduate industrial designers meet your companies' expectation?". According to answers as seen in Figure 6, none of the companies found 100 % matched industrial designer, and the majority replied that new graduates met as only 50 % as their expectations.

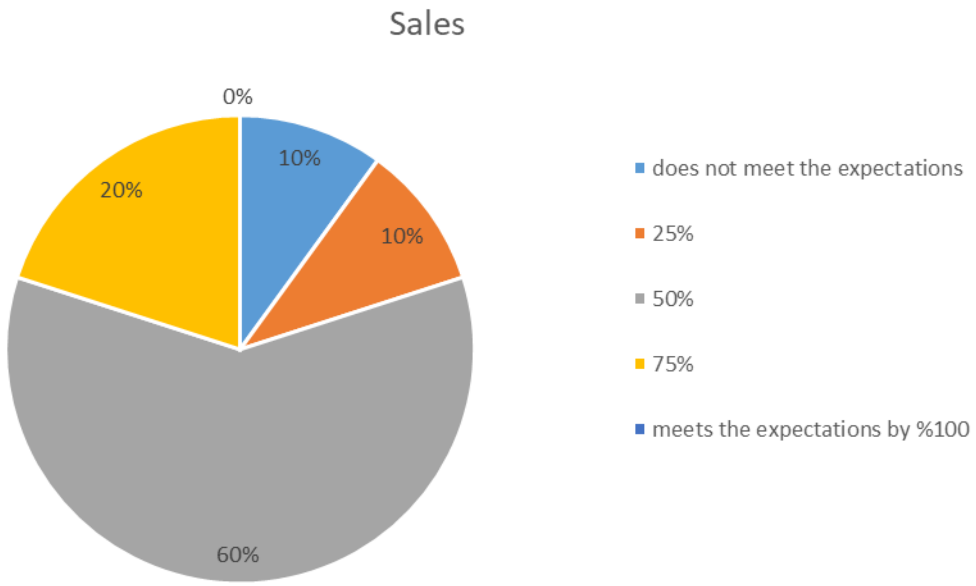


Figure 6. Companies expectations and meeting them with new graduates' ratios

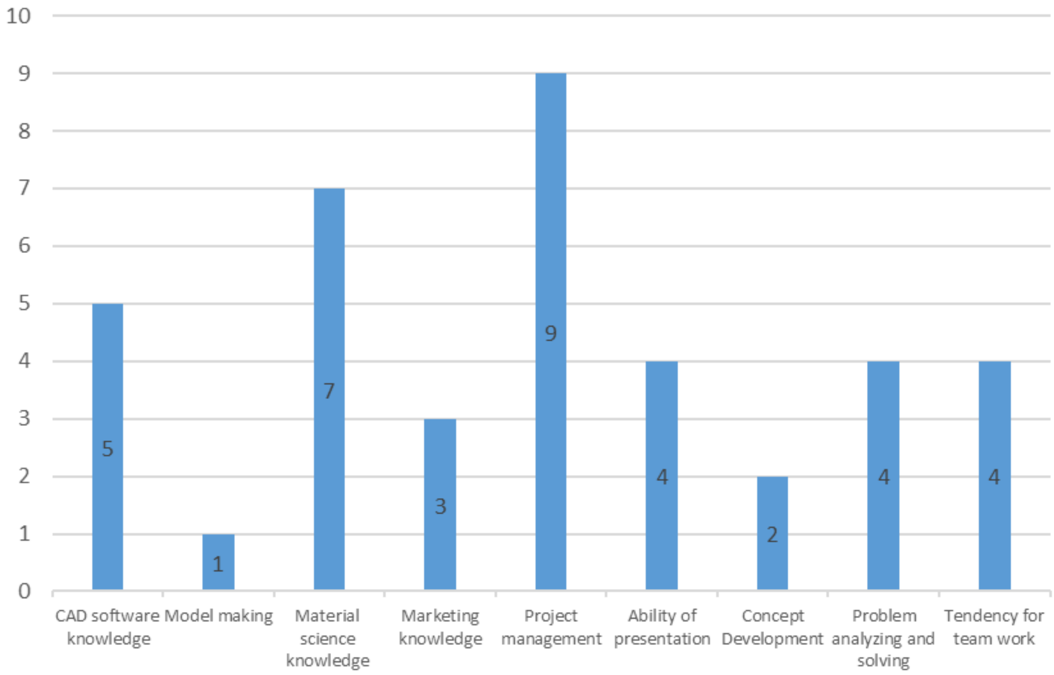


Figure 7. Insufficiency in specific subjects of new graduates according to companies

The following question in Figure 7 asks in which skills and knowledge new graduates have an insufficiency. In contrast to companies' expectations, they do not have enough knowledge in project management and technical subjects. However, companies want more qualified new graduates in teamwork and concept development.

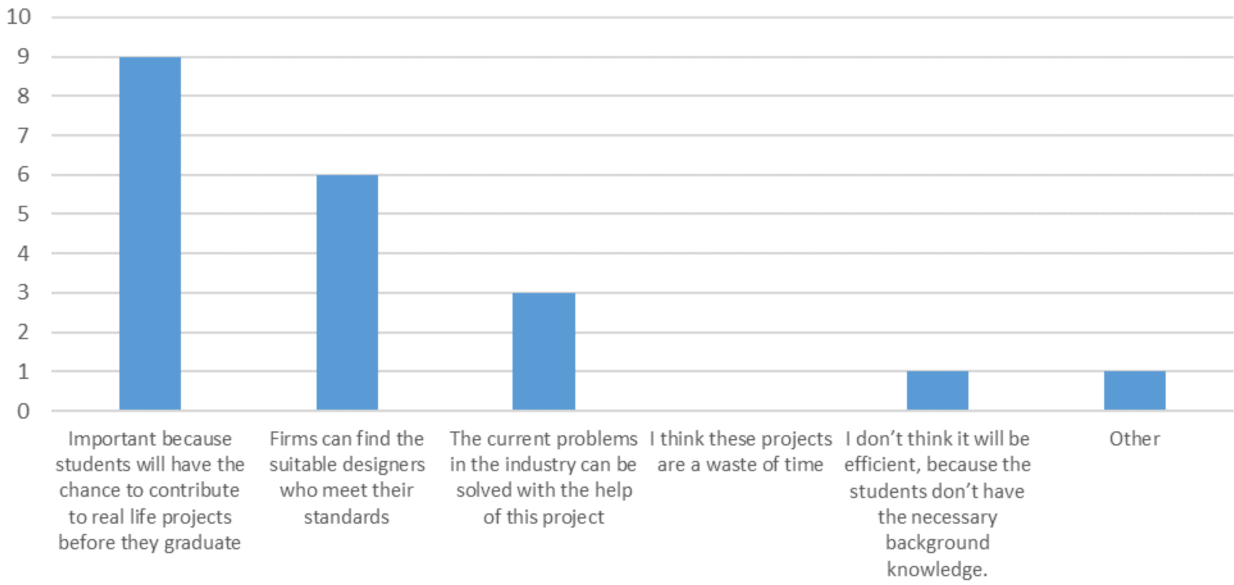


Figure 8. Companies opinion about UIC with industrial design departments

As seen in Figure 8, the majority of companies think UIC with industrial design departments are important, because thanks to UIC projects they can have opportunities to work on real projects before graduation. Moreover, when the answers are examined, 5 participants who agree with majority opinion select one more opinion that is that companies can reach designers who are suitable for them.

Participant companies or designers never contributed to any facility for industrial design project labs or workshops, but 30 % of them plan to in the future.

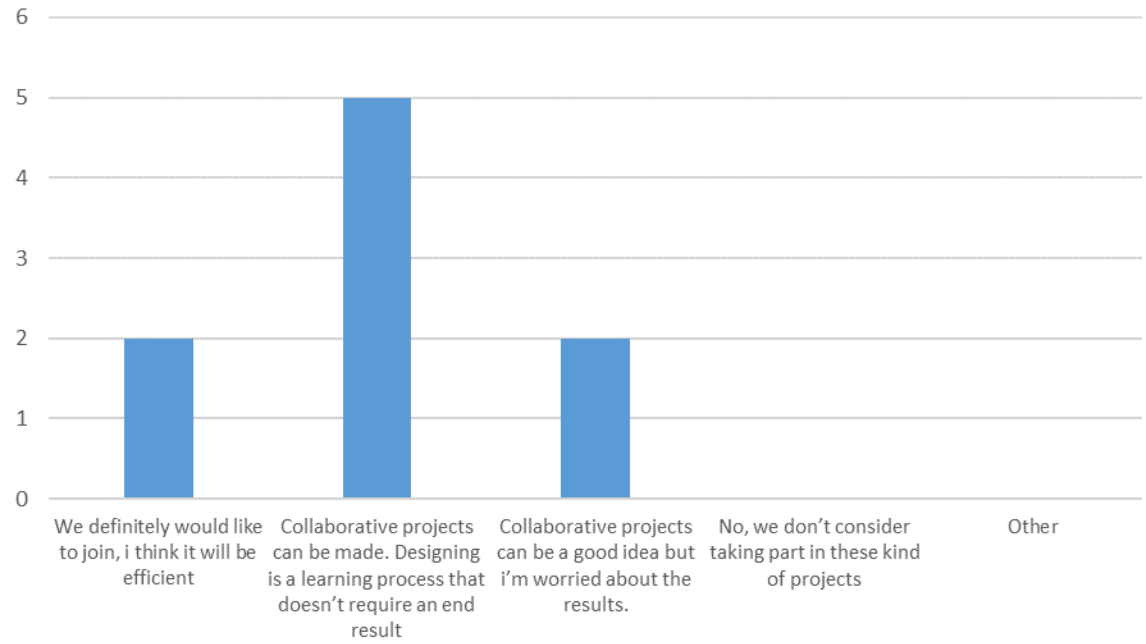


Figure 9. Companies and designers' tendency for UIC

In Figure 9, how much companies and designers are willing to collaborate with universities is asked, and according to answers, opinions of the majority is that UIC projects are possible, and there is no obligation to reach to results, because the important point in UIC is the process of learning together.

When companies or designers' additional opinion is asked at the last question, one response was "Before graduation, students should learn different department's needs, project management, and concept of business analysis, because these make advantage in business life. Thus, internships, teamwork and projects are important to gain experience".

Results

1. When compulsory courses are examined in terms of general characteristics, both industrial design programs have similar structure. However, when the percentage of characteristics of each course is calculated, there is difference in PDP+DT+DS characteristic between LNU and IZTECH. LNU has more courses in PDP+DT+DS, while IZTECH has more courses in PDP+DS.
2. In LNU, characteristics are equally distributed into elective courses, but there is no balance in IZTECH. When characteristic of each courses are examined, LNU offers each of them, except only DT characteristics, however, there is some deficient characteristic in elective courses, which are offered by IZTECH. PDP+DS and PDP+DS+DT are lacking characteristics.
3. Expectations of companies and designers from new graduates can be listed, according to rate of definitely required and required; tendency of teamwork (8/10 definitely required), concept development (8/10 definitely required), problem analysis and solving (7/10 definitely required), CAD software using (4/10 definitely required), material science

knowledge (6/10 required), manufacturing techniques knowledge (6/10 required), communication with other departments (6/10 required), project management (5/10 required).

4. New graduate industrial designers meet 60% companies' expectations in 50%, and 20% of companies think that new graduates meet expectation in 75%.
5. According to companies, new graduate industrial designers lack qualification in terms of project management, material science knowledge, manufacturing techniques knowledge and CAD software using ability.
6. The majority of participants agree "UIC is important for industrial design departments, because thanks to it, students take opportunity to work on real projects."
7. In terms of tendency of companies and designers for UIC, they agree that collaborative projects can be done; there should not be obligation to reach tangible results, because design is a learning process.

Conclusion

There are two methodologies, which are applied in this research, and they aim to determine reasons for the limited engagement with UIC in IZTECH. To reach a result, outcomes of two methods are compared and the relationship is built to see how UIC can be developed in IZTECH.

The missing subjects are under PDP and DT characteristics. According to Figure 2 and Figure 4, both compulsory and elective courses offer limited number of DT characteristic courses that provide knowledge and experience about project management. DT is a side characteristic which means that there is no course with only DT characteristics as seen Table 1, because DT makes courses more advance and adds team work, concept development etc. which are the most wanted qualifications by companies or designers according to survey result as seen Figure 5.

To make the curriculum more suitable for UIC, adding new courses is not the only option, making improvement like adding team projects, or other research assignments can contribute curriculum.

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Review

Mastering Primary Design and Technology

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Introduction

It is refreshing to read a book devoted to teaching Design and Technology in the primary classroom. I was hooked as soon as I read in the introduction when author Gill Hope stated that she was using the full term 'Design and Technology' throughout the book and not abbreviated to 'D&T' or 'dt'. Her reasons "the danger of using such abbreviations is in forgetting what they stand for" (p2). I agree with this whole heartedly as I think it is very important to emphasise the design component of Design and Technology Education as this distinguishes this curriculum area from classes that involve "just making stuff".

First introduced into the national curriculum in 1990 in England and Wales Design and Technology known elsewhere as Technology Education or Technology and Engineering Education has been implemented around the world for children from aged 3-13 (Benson & Lunt, 2011). However, in recent years technology has found itself competing for time in both the primary classroom and in initial teacher education programmes. For example, in New Zealand Technology Education (Design and Technology) the primary classroom along with science and social children among others has taken a back seat due to a significant focus on literacy and numeracy and the implementation of national standards in reading writing and numeracy by the previous government nine years ago. Declining hours available to student teachers' instruction time in Design and Technology education has also contributed to the limited classroom experiences in Design and Technology for many primary children before they enter secondary school (Forret et al., 2011). This has means that many secondary teachers struggle to attract children to their discipline because children do not understand what it is, or they have had experiences labelled as technology, which in fact were merely making activities. Those who are attracted have considerable catch-up to do to ensure they are ready for senior secondary assessment and examinations within two to three years of beginning high school.

It is therefore useful to have this book dedicated to the teaching of primary Design and Technology and although written the English context I have found it very relevant to my own New Zealand context. The book offers a range of features within each chapter to inform and engage the reader in critical thinking about implementation of Design and Technology. Features include: a chapter overview, case studies, places to pause and reflect on chapter content, examples of children' work and relevant excerpts from policy documents. Most are applicable internationally and well as in England and Wales. In this review I begin with an overview of the book and then review each chapter in more detail.

Book Overview

The early sections of the book include a contents page, a list of figures and a list of tables to guide the reader through the book. The List of Tables is followed by a foreword by the series editors Judith Roden and James Archer who begin with the identification of two main target audiences for the series, both beginner and experience teachers. They identify aims of the series including to introduce current and contemporary practices within each curriculum area. They also hope to equip student teachers and beginning teachers with enough understanding and knowledge to achieve mastery in the curriculum areas. The series editors' foreword is followed by a 'How to Use this Book' section also written by the Roden and Archer and which, concludes with an introduction to the author. Following a subsequent Acknowledgements section, the Introduction offers a chapter synopsis and a rationale for the exclusion of Early Years Design and Technology from the book, which does cover from children five years and older. A Glossary on p.6 defines several terms related to Design and Technology that are often misunderstood or have multiple meanings in the wider world such as technology and model (both noun and verb). The book comprises of eight further chapters, each outlined below.

Chapter Outlines

The eight chapters of the book use the same format. Each begins with a list of bullet-pointed chapter objectives giving useful insight into what is coming. Throughout each chapter, there are opportunities to reflect on what the author is saying and suggests the reader consider implications for their own lives. Several case studies throughout the book exemplify key ideas the author is making. Chapters conclude with a summary and a list of recommended readings.

Chapter 1: An Introduction to Primary Design and Technology

This chapter introduces the reader to Design and Technology. The chapter synopses states that the chapter leads to consideration about the importance and relevance of technology education. The chapter begins by placing technology at the heart of what it is to be human. This is an excellent place to start when considering technology. It is vitally important to recognise that making things and changing the world around us are innate human activities, and thus warrant considerable study. The first Pause for thought" section encourages the reader to focus on their personal relationship with technology, technology's relationship to science and any experiences of design and technology at school. The chapter continues with a definition of technology as “basically everything designed and made by humans” (p11). This definition has a strong focus on artefacts and systems related to feeding ourselves, keeping warm, movement, and defence. The definition is somewhat narrower than the fours aspects Dakers (2017) discusses in Springer 2017 International Handbook of Technology. As well as the artefacts and systems developed by humans Dakers, drawing on Carl Mitcham’s work, suggests technology is knowledge, different from science, to be studied and learned. He also suggests that technology is developed processes, the actual designing and making processes developed. The fourth aspect relates to the social value of technology and including ethical and environmental considerations. Some aspects of the latter are hinted at by Hope was she talks about human impact on the planet and the role technology has played in this. Further discussion distinguishes technology from art, with an emphasis on the purposeful intervention of technology. England and Wales Design and Technology Associations’ “Star Diagram” reminds us of six aspects involved in designing and making, number of which offer a distinction from Art. Unfortunately, the URL given for locating the star diagram was inaccessible on the D&T website.

The chapter continues by offering a strong education-based rationale for teaching technology and infers the ubiquity of technology and the skills and abilities necessary for design and development of successful products such as: it offers satisfaction, develops self-confidence and higher-level thinking as well as empathy and understanding of other people’s needs and wants. It is refreshing to see an education-based rationale for technology implementation in the curriculum rather than a fiscal, economic or political rationale often seen. The final section of the chapter enhances the rationale by outlining further learning and developmental benefits for children by adding to their sense of agency and well-being. I particularly appreciated the ‘State of Flow’ or deep connection reference (Csikszentmihalyi, 1990), as this is a connection I too have made to children’ involvement in technology although originally identified in a physical context of playing sport.

Chapter 2: Current Development in Design and Technology

Chapter 2 offers insight into current development in design and technology within the English context and begins by offering a brief history of Design and Technology in England. Reflection into where a curriculum has come from is critical when undertaking development and change. Insight into past success and failures ensures against repeated mistakes, and that curriculum design is forward facing. The current state of technology in primary schools is then give with reference to Ofsted reports from 2008 and 2016. This comparison offers insight backward progress in terms of children’ engagement in design in favour of making “successful products”. This appears to reflect the product-based nature of the curriculum or perhaps the perceived success of product development as opposed to additional value given to processes, knowledge and ethical considerations developed when designing is a strong component of the curriculum.

The penultimate section of the chapter offers insight into potential areas of integration across a range of other curriculum learning areas (subjects). Integration offers several benefits for both teachers and children. An integrated programme is more time efficient, activities and learning are assessed from multiple perspectives and engagement and motivation are high as learning is authentic and contextually based. There is one danger of integration that is worth consideration and exploration in this text. This is was I call “Mucky Brown Paint Syndrome” (Fox-Turnbull, 2012b) and indicates that busy engaged children are not always learning key concepts and ideas in each of the applicable learning areas, indeed sometimes they are not even aware of subject content or concepts they are meant to be learning.

The chapter’s final section compares Design and Technology in England to that of other English-speaking nations such as: New Zealand, Malta and South Africa who offer a number of similarities, especially an emphasis in design. I too can see several similarities to technology in the New Zealand curriculum such as a strong emphasis on design and modelling design ideas. There are however a number of significant differences the main one of which is a focus in the New Zealand technology curriculum on the nature of technology and identification of technological knowledge unique to the discipline (Ministry of Education, 2007). These two aspects make up a significant portion of the curriculum through the delivery of two strands of learning by the same names: ‘Technological Knowledge’ and ‘The Nature of Technology’.

Chapter 3: Design and Technology as an Irresistible Activity

An error in the second paragraph of the Chapter Synopses on p.2 attributes current development and national comparisons to this chapter, when in fact they all belong in Chapter 2 as mentioned above. The third paragraph of the Synopses correctly identifies that Chapter 3 discusses what it is about technology that is so engaging for children. This section rightly attributes a large range of key ideas to primary children’s engagement in technology. These include the hands-on nature of the activity, that students can see real progress in terms of tangible outcomes and that it allows them choice, trial and error encompassing the evaluation of their actions. This thinking certainly aligns with my experiences of teaching technology in primary school. Another related benefit I always enjoy making explicit to children and the student teachers with whom I now work is that in technology mistakes are “cool” and something to celebrate and learned from. Students are often unaware of the “work” they are doing in technology. The play-based nature of the tasks certainly assists with engagement. Other benefits mentioned in the chapter are the improvement of the physical and kinetic skills, development of higher-level thinking, social skills such as collaborating, compromising and negotiating and numerous specific skills “borrowed” for other learning areas such as writing, measuring, drawing, understand the relationship of forces and materials as well as confrontation with various moral and ethical issues.

The second section of the chapter deals with the iterative nature the technological process from early design ideas through to final product development. It presents a number of well-known models of technology practice, related to the need for design theory to augment creatively to ensure a worthwhile technological outcome. Of particular value are Middleton's 'problem zone' which illustrates the potentially chaotic nature of designing and Kimbell's APU model which emphasises the iterative nature of designing as well as balance between cognitive and physical activity. The chapter concludes with a number of "classroom stories" which clearly illustrate key points made throughout the chapter.

Chapter 4: Design and Technology as a Practical Activity

Chapter 3 provides examples of the types of activities done in the primary classroom that constitute technological activity. This chapter offers useful guidance for teachers thinking about teaching technology. It identifies considerations teachers need to make when identifying potential products to be designed. Usefully it also defines 'product'. I note that this chapter has a heavy focus on products. In New Zealand, as well as others, students are encouraged and taught to design systems as well as products as both make up our "designed world". The chapter is well-illustrated with a range of actual examples of students' work in technology from all five areas of technology: structures, mechanisms, electrical control, textiles and food. I suggest that the area of electrical control does involve the use of electrical systems, however very little is mentioned about inputs and related outputs nor the design of the system, but rather using an electrical system to develop a product.

Chapter 5 Skills to Develop in Design and Technology

The main skills discussed in Chapter 5 include aspects of procedural knowledge. These include designing for others, modelling and reflective activity. The chapter begins with a rationale for the inclusion of procedural knowledge in Design and technology. This supports McCormick's (1997) who identify that both procedural and conceptual knowledge is critical to technology practice and Jones and Moreland (2001) who also identify procedural and conceptual knowledge, as well as technical and societal knowledge a key components of technology practice.

Six skills identified as necessary when students are working with users include: need identification, evaluation of existing designs, generation of ideas, communicating and accepting feedback, product making and evaluation of product and process. Usefully Hope emphasises that these are not a lesson-by-lesson account of what will happen, but merely emphasise the iterative nature of technology practice as outline previously in Kimbell's APU model of technology practice.

Parkinson's '5 M' model used to classify underlying skills needed for successful technology practice is critiqued in the next section of this chapter. The five Ms stand for: Making, Modelling, Manipulating, Mending and Modifying. Jointly developed and published with colleague Parkinson, Hope offers a suggestion that perhaps the last four are indeed subsets of the first. Modelling, mending, manipulating and modifying are in fact all subsets of the process of making. I agree with this point and take this critique somewhat further by suggesting that 'manipulating' and 'mending' are likely to be subset of modelling, as indeed could 'modifying'. It is also important to recognise that adaptation is significantly different to modification and an equally important part of technological practice. Alluded to in the chapter, however a clear distinction between the two might have been useful.

Chapter 6: Children's Ideas- Promoting Curiosity

An aspect that is particularly relevant to technology education is that of promoting curiosity. I was delighted to find this chapter in the book. We often hear and read about the need for creativity in technology (Benson & Lawson, 2017). Often attributed to science education but rarely technology, curiosity is identified as a critical component of technology in this chapter. The balance between being curious about how the technological world works, creating functioning products and thinking creatively need careful balance. This chapter offers useful range of ideas to pique children's curiosity about the made-world. It also offers insight to ensure transfer of knowledge gained from investigations and queries to technology practice. I especially like the idea of product collections. Useful ideas provide guidance for the setting up of such collections. I know of several collections of technological artefacts owned by colleagues: potato peelers, children's jigsaw puzzles, scrubbing brushes to name a few, used to foster curiosity and critique about design and design features.

Another technique suggested to develop curiosity mentioned in Chapter 6 is the use of children's existing knowledge and experience to contribute to their understanding of the world. This aligns well with the idea that students come to school with 'Funds of Knowledge'(González, Moll, & Amanti, 2005) from their local community, family and culture that assist them in making sense of and contribute to school learning especially in technology (Fox-Turnbull, 2012a). Hope also suggests that prior school learning in technology and learning other curriculum areas also contributes to students' learning about the technological world. These ideas are supported and further explored in greater depth in my PhD thesis (Fox-Turnbull, 2013).

Chapter 7: Assessing Children in Design and Technology

The taking a test or an examination in technology clashes with its underlying philosophy. Summative assessment has a limited role in technology, therefore it makes perfect sense that Chapter 7 focuses on assessment FOR learning or formative assessment of technology and begins with an explanation of formative assessment and the role self-assessment plays within it. The chapter then demonstrates how self-assessment can be undertaken within a technology context. The chapter concludes with a look at the Key Stages 1 and 2 Progression framework and how it is used for assessment of technology. The chapter closes with a mention of longer term planning and assessment and how several curriculum areas or subjects can be assessed within a technology project. The strong linking between formative assessment and technology is sound, as intimated above. However, I think the chapter could have been of more use to teachers if it had considered how learning intentions-the recognition of intended learning and success criteria-what success of the intended learning looks like had been included. The writing of context free learning intentions and specific success criteria assist teacher driven assessment and guide self and peer assessment (Clarke, 2008) and work particularly well in technology (Fox-Turnbull, 2012b).

Chapter 8: Practical Issues

Finally, Chapter 8 looks at practical issues for implementing technology at a school-wide level. Because of its practical, hands on nature technology offers several challenges for schools as they implement it across all levels. Hope starts by considering the 'bare minimum' identified by the Design and Technology Associations' Expert Advisory Group for Primary Schools. Other very relevant aspects of consideration for schools discussed briefly are Health & Safety and Inclusion & Diversity. In technology, something as simple as being left-handed can significantly disadvantage a child as many practical tools are designed for right –handed people. It is useful to acknowledge that something as simple and common as this relates to student inclusion. This mention has the potential to trigger the identification of other areas of impact on students' wellbeing in technology.

The chapter concludes with a brief but useful discussion about developing personal professional knowledge in technology and the consideration of subject leadership. Ongoing professional development and leadership are significant and considerable issues in technology, especially in recent times when funding for professional development seems harder to get. More and more teachers are being asked to be responsible for their planning their own profession development and to take voluntary leadership roles to assist others in this journey. This offers a challenge to technology given that it is a relatively recent addition to national curriculum.

Conclusion

This book offers an overview into several key ideas related to implementation of design and technology in the English and Welsh primary school. I expect it will be of greater interest to those who teach design and technology in these countries, however I found the book to be engaging and informative, with a format that lends itself as a text for student teachers and or teachers undertaking professional development in technology. It lays down a number of key foundational ideas and uses children's work to illustrate ideas as well as offering numerous opportunities for reflections and discussion.

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