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

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

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

1 INTRODUCTION

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

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

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

2 RELATED WORK

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

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

3 DESIGN DOCUMENTATION

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

3.1 Definition of Design Documentation

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

3.2 Purpose of Design Documentation

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

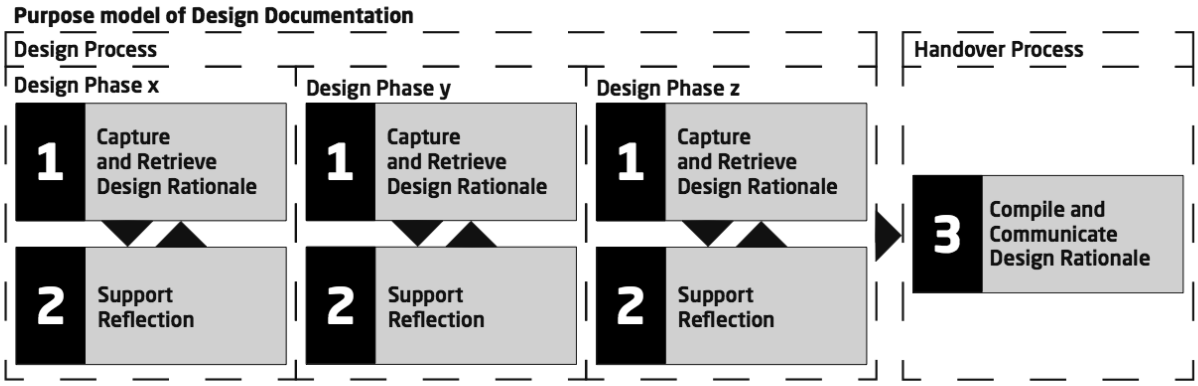

Figure 1. Purpose model of Design Documentation

3.2.1 Capture and Retrieve Design Rationale (P1)

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

3.2.2 Support Reflection (P2)

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

3.2.3 Compile and Communicate Design Rationale (P3)

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

3.3 Discussion

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

4 INTRODUCTION TO THE LOGCAL

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

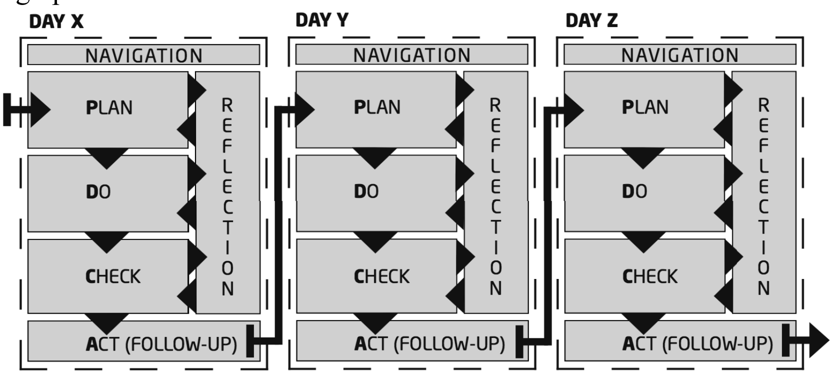

Figure 2. LogCal scheme with embedded PDCA cycle

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

5 EXPERIMENT SET UP AND EVALUATION

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

5.1 Setting

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

5.2 LogCal Analysis Based On Grounded Theory

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

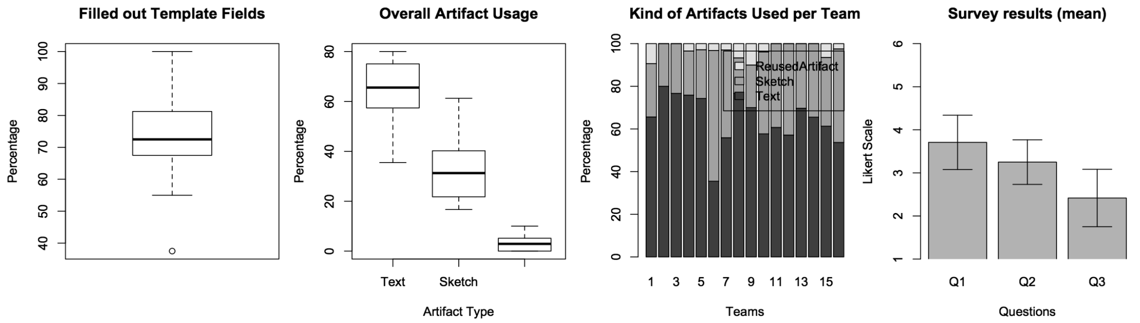

Figure 3. Left: Filled out template fields; Middle: General artifact usage; Right: Survey results

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

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

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

5.3 Interpretation of Data And Deduction Of Hypotheses

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

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

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

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

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

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

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

5.4 Threats to Validity

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

6 FUTURE WORK

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

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ELEARNING AND EMAKING IN PRODUCT DESIGN EDUCATION

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

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

1 INTRODUCTION

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

2 SUPPORTING AN ITERATIVE DESIGN PROCESS

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

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

2.1 Organisation of space

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

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

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

3 STUDENT CENTRED LEARNING

3.1 Connecting to learning

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

3.1.1 Flipped classrooms in design learning

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

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

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

3.2 Connecting to the global environment

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

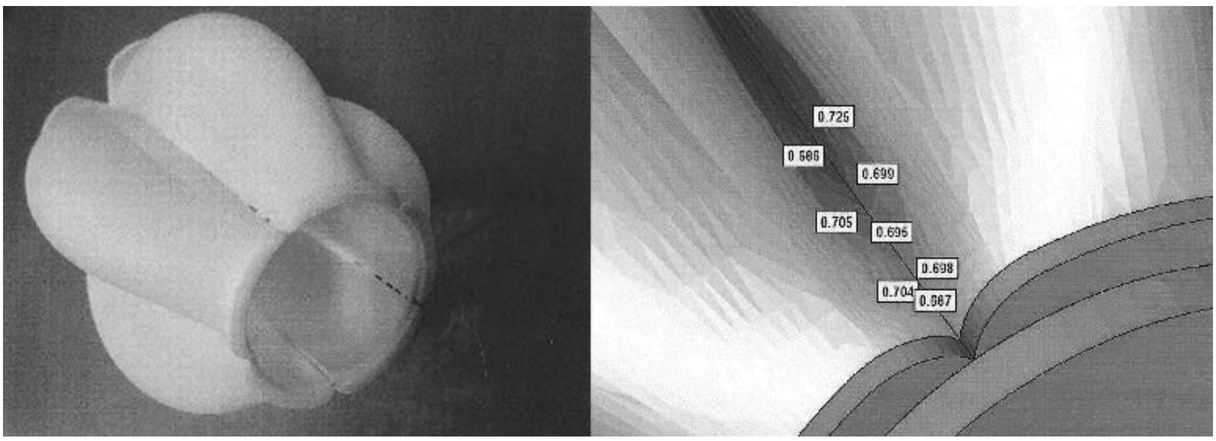

Figure 2. Print failure report from Shapeways showing insufficient wall thickness in the seams

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

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

3.3 Connecting to issues

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

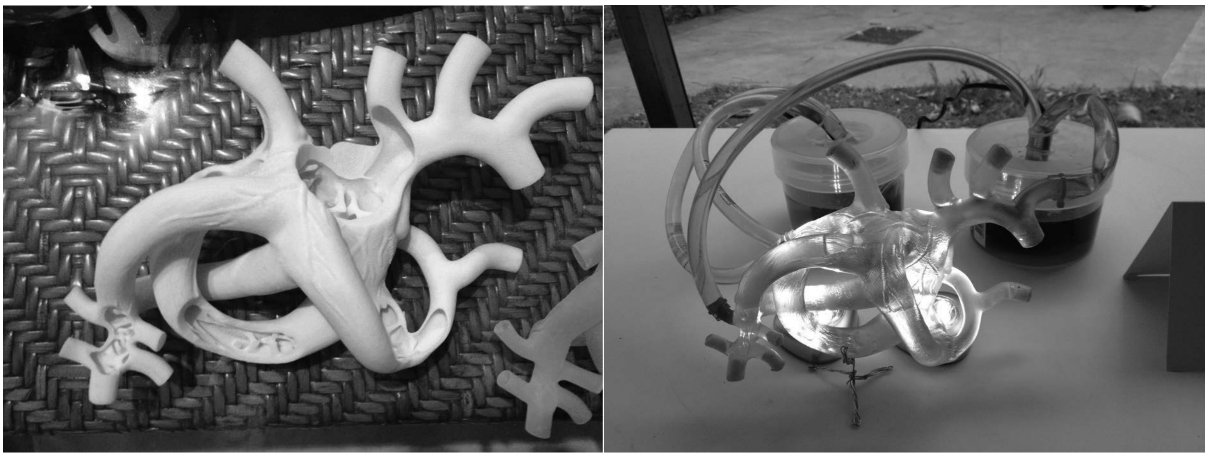

Figure 3. Heart provocation models by MA student Kaecee Fitzgerald (a) 3D print from the CAD model; and (b) 'Double pump' heart in action showing flow

4 CONCLUSION

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

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

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

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

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

1 INTRODUCTION

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

2 SOCIAL DESIGN PROJECTS

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

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

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

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

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

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

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

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

Figure 1: Technology in Social Design Projects

3 THE ROLE, INFLUENCE AND VALUE OF TECHNOLOGY

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

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

2.1 Final considerations

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

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

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

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

1 INTRODUCTION

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

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

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

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

2 THEORIES OF HUMAN-TECHNOLOGY RELATIONS

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

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

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

3 IMPLEMENTATION IN THE CURRICULUM

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

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

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

4 EXAMPLES

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

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

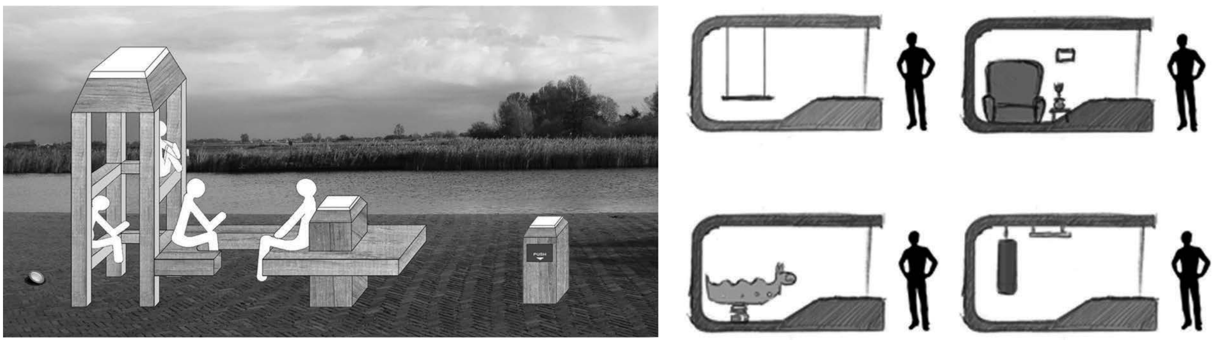

Figure 3. Street furniture concepts by Jessica Schraa (left) and Hieu Nguyen (right), 2011

Figure 3 shows two student results of the course. The 'Loswal' concept by Jessica Schraa is a hangout for tourists in a typical Dutch Canal-side environment. The concept does allow for different arrangements of people like the garden table in figure 2. It caters for sitting alone or together and also in a high or a low position for different views on the landscape. The concept also mimics typical harbour equipment. The bus shelter concepts by Hieu Nguyen work in a slightly different way. They do not so much emphasize the physical relationship with the street furniture but rather a psychological one. The passengers that have to wait in the bus shelter are invited to spend their time playing around with the objects that are added to the simple shelter. The somewhat unusual objects therewith also have a second function as conversation starter between strangers.

The second example, comes from the master course Create the Future. Although industrial design is always future oriented by nature, in this course students have to develop an innovative product for in at least 25 years' time, and have to design the future context for their product themselves with the aid of scenario development [9]. The technology involved here is more advanced, especially because the students can make use of the expected developments in future technology, based on Delphi Studies. The design concept that is shown here is made for Philips healthcare. To quote the students themselves: "future studies allow companies to explore and pursue future opportunities. Therefore it is an important skill for designers to be able to develop and work with a long term vision." [10] p.7].

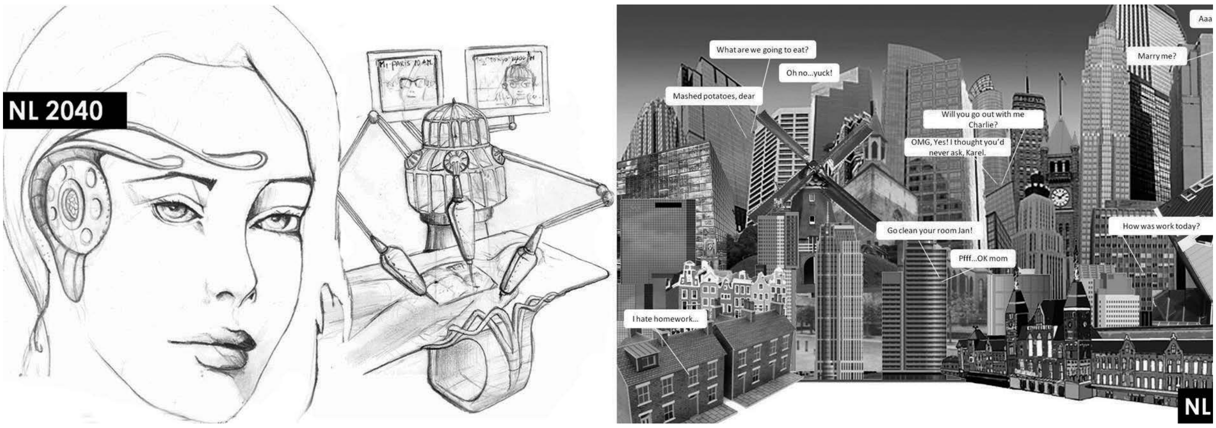

Figure 4. Scenario visualization "Healthcare in the Netherlands in 2040" by Ida Nordlöf, Liesbeth Stam and Ani Hovhannisjan (2012)

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

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

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

5 COMMON GROUND

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

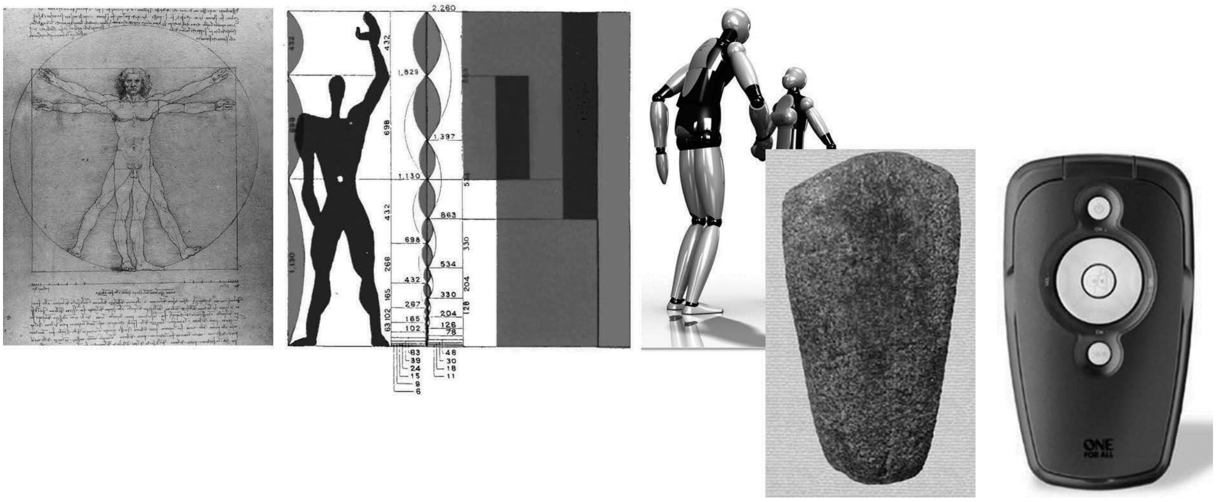

Figure 6. The Vitruvian man (ca.1490), the Modulor (1948) and a contemporary 3d Human Model (Dined). Below a fist-axe from the Neolithic and a contemporary remote control.

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

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

6 CONCLUSION

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

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INTRODUCTION OF ISSUES REGARDING PEOPLE WITH SPECIAL NEEDS TO DESIGN EDUCATION

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

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

1 INTRODUCTION

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

2 FORMULATION OF THE PROBLEM

2.1 Who are the people with special needs

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

2.2 Need for designing an accessible environment for all

By the beginning of 2014 according to the statistics 686 812 Bulgarians are with permanent physical disabilities in Bulgaria. This represents almost 11 % of the total population in the country. Throughout the European Union, the records show that around 15-16 % of the population have some kind of disability. That amounts almost 80 million Europeans that are still discriminated and physically restricted. [1]

Society as a whole begins to understand that it has to adapt to their needs, not vice-versa. People with disabilities should be able to lead satisfactory life and decide freely for themselves. The network offers great potential to improve the social integration for people with disabilities (online operation, e-democracy, access to knowledge and information). However, particular attention should be paid to the issue of accessibility. Serious problem for labour and social equality for people with disabilities represents the accessibility to the surrounding environment. According to the National Institute of Statistics in Bulgaria by 2005 only 5 % of the disabled people admit their surrounding environment as easily accessible, 46% have encountered some difficulties, and 24% identify it as inaccessible (there is not applied information for the rest 25%) [2].

In Bulgaria there is a regulatory act since 2003 for accessibility of buildings, transport, and facilities. More than 10 years after it has been inured, there is still no significant adaptive projects for people with special needs. The greater part of the improved urban spaces and facilities after 2003 has serious gaps in the requirements for disabled people. On the other hand in the process of designing the needs and necessities of these people are considered too late.

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

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

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

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

The design and organization of the urban and interior environment are those who can offer a solution to the mentioned problems.

From everything that is observed directly, the authors believe that the boost in solving these kind of problems comes from young designers who after graduation will be factored into practice and engaged in this cause. Design students need an extensive examination of the various types of disabilities and difficulties that these people face. Thus future designers would be more responsible while designing, in order to meet the relevant requirements for the people with special needs.

Today, the capital city of Bulgaria, Sofia, which is among the oldest European capitals, still has to solve many problems regarding the disabled people. Although the alert in various media and

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

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

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

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

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

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

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

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

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

1. Development of the project for urban facilities design got transformed into "Playground for Art Therapy." In the process of creation the student meets different types of art therapies, gets familiar to the fundamental requirements for facilities for disabled and healthy children design and safety regulations. Consultation with experts is required, where necessary.

   The playground has two facilities: musical whirligig and water pump.

   Musical whirligig for children without disabilities and children in wheelchairs. In the base of the whirligig there is an installed hurdy-gurdy. The rolling plays preliminary chosen music melody. Rotation helps to strengthen the vestibular system, and the music acts as a therapeutic tool.

   The second part of the playground is water pump with wooden channels in which the water drains (designed by the company Richter Spielgeräte GmbH). Next to the channels there is a pool with clay. By using clay and water children can create different forms themselves. This therapy develops children’s haptic sensation. It is believed that in most cases the water has relaxing features. In some cases of mental disabilities if modelling with hands incite interest in the child, it might be a sign of future development.

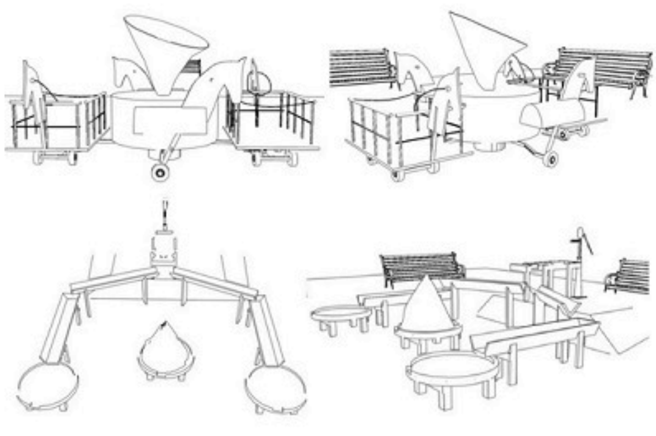

Figure 3. Proposed design elements for the playground

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

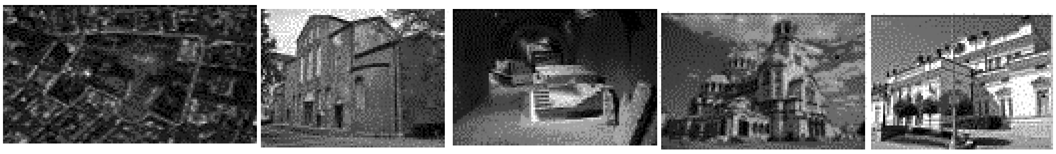

Figure 4. Borders of the developed area and part of the included objects

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

Along with general requirements in the area, there are specific problems related to the usage by people with disabilities. Therefore the project provides in the zone facilities and furniture with the following elements of urban design:

Ramp with the required size, gradient, handles and flooring for the garden in front of the Church “St. Sofia” and the Cathedral “St. Al. Nevski”,

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

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

3 CONCLUSION

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

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

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

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

1 INTRODUCTION

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

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

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

2 USER EXPERIENCE AND EYE TRACKING

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

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

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

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

Figure 1. Mobile eye tracking glasses with recording unit

3 MOBILE EYE TRACKING IN DESIGN EDUCATION

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

3.1 Case 1: Power tool for direct fastening

3.1.1 Product and application

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

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

3.1.2 Investigation in user experience by mobile eye tracking records

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

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

3.1.3 Awareness for user experience in education

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

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

3.2 Case 2: Electric bicycle

3.2.1 Product and application

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

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

3.2.2 Investigation in user experience by mobile eye tracking records

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

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

3.2.3 Awareness for user experience in education

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

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

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

3.3 Case 3: Peritoneal dialysis device

3.3.1 Product and application

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

3.3.2 Investigation in user experience by mobile eye tracking records

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

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

3.3.3 Awareness for user experience in education

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

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

5 CONCLUSIONS

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

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

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

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

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REFLECTION IN DESIGN EDUCATION USING VISUAL TECHNOLOGY

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

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

1 INTRODUCTION

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

It has been a century since John Dewey published his theories of how we think [2]. The book discusses many ways of thinking, including reflection. In 1938, Dewey [3] defined reflection as: *“An active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and further conclusion to which it tends.”* According to Schön’s [4] description, reflection often takes form of a reflective conversation with a situation. Amongst others, a discovery of new levels in a situation emerges in this conversation. In addition, the conversation can reveal recognition of feelings a situation can evoke, consciousness of choices made and the grounds for them, and ideas and anticipations that help to address meaning [5]. In this conception, reflection is about learning from experiences, as Dewey [6] claimed. As Dewey [3] wrote: *“What (an individual) has learned in the way of knowledge and skill in one situation becomes an instrument of understanding and dealing effectively with the situation which follow. The process goes on as long as life and learning continue.”* It is important to emphasize that the mentioned writers all view reflection as more than opinions on a theme or a situation. A reflective process should raise questions of a social, political, or cultural character and challenge assumptions and "certainties" that underlie practice [7, 8]. Boud et al. [9] defined reflection as a *"generic term for those intellectual and affective activities in which individuals engage to explore their expressions in order to lead to a new understanding and appreciation."* Through this, they emphasize the importance of feelings in the field, a notion that was elaborated on previously by Lindeman [10], who viewed reflection as a tool to start a process using knowledge, feelings, and experiences to understand and solve a problem. The process of reflection was considered a lasting and ongoing process by Schön [4] which he described as "reflection-in-action." In this way, he introduced the idea of reflection being not only a glance at the past on something that had been or was a retrospective process, but also an ongoing action to connect knowledge and practical experiences. John Sandars' [11] definition of reflection corresponds with Schön's view. He described it as a *"metacognitive process that occurs before, during and after situations with the purpose of developing greater understanding of both the self and the situation so that future encounters with the situation are informed from previous encounters"* [11].

Until recently, literature and research within the field of reflection almost solely considered reflection to be a written task. In an effort to make Dewey's thinking more accessible, Carol Rodgers [12] distilled four criteria from his writing. Her third and fourth criterion is of relevance for this article. Her third criterion is as follows: *"Reflection needs to happen in community, in interaction with others."* This is an interesting statement, as reflection is often performed individually. In Rodgers fourth criterion, she states that *"reflection requires attitudes that value the personal and intellectual growth of oneself and of others."* This shows that Dewey considered reflection to be more than a personal matter; rather, it should be done in interaction with others and be beneficial to others. This was later supported by Kemmis [7], among others, who referred to reflection as a social process, and by Vince [5] and Raelin [13], who argued for a shift from individual to collective reflection. The idea of reflecting in groups and sharing reflection is interesting. Over the past few years, the field of reflection has developed, and research and practice related to the creative use of digital media and storytelling has started to evolve [11]. In particular, digital storytelling has been invoked in this sense [11, 14, 15]. The Oslo and Akershus University College of Applied Sciences has run a project called Digital Storytelling for Learning [16]. In this project, they have among other things worked with reflections from practice. They describe a digital story as *"a short personal 'film' produced by the narrator. The story is supported by photos, (videos) and soundtracks. The editing is done in accessible and easy to use software."* The favoring of digital storytelling instead of film as a reflective tool is probably related to the openness and lack of professional pressure these new multimedia tools offer. The reflector needs less technical knowledge to create a digital story than is required for a film. Using multimedia containing elements like images, sound, voice, text, time, and animation in a film, opens new ways of expressing yourself. A multimedia approach can also inspire to make the presentation public, thereby sharing the reflection.

2 BACKGROUND

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

2.1 Research question

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

3 METHOD

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

3.1 The first workshop

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

3.2 The second workshop

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

4 FINDINGS

4.1 The first workshop

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

4.2 The second workshop

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

5 DISCUSSION

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

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

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

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

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

6 CONCLUSION

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

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

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ANTHROPOMETRICS 2.0: ENRICHMENT OF CLASSICAL ANTHROPOMETRY THROUGH MULTIDISCIPLINARY COLLABORATION

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

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

1 INTRODUCTION

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

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

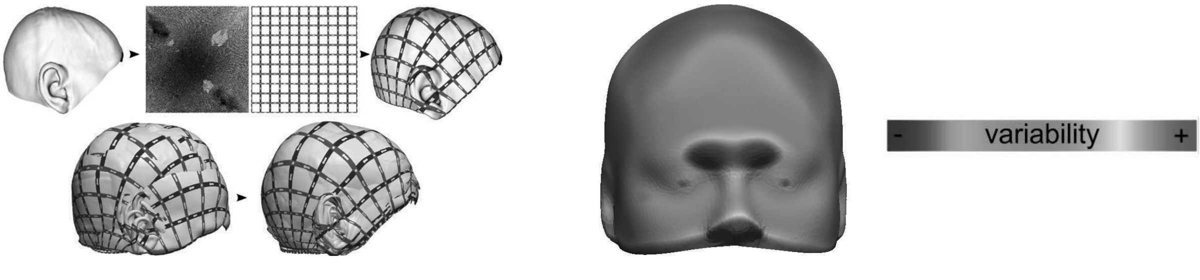

Figure 1. Building of a statistical shape model from medical images (left): a collection of head forms is retrieved from MRI images, annotated and mapped to coordinate grids, and aligned. As a result e.g. a mean shape with the variation at each point can be visualized (right)

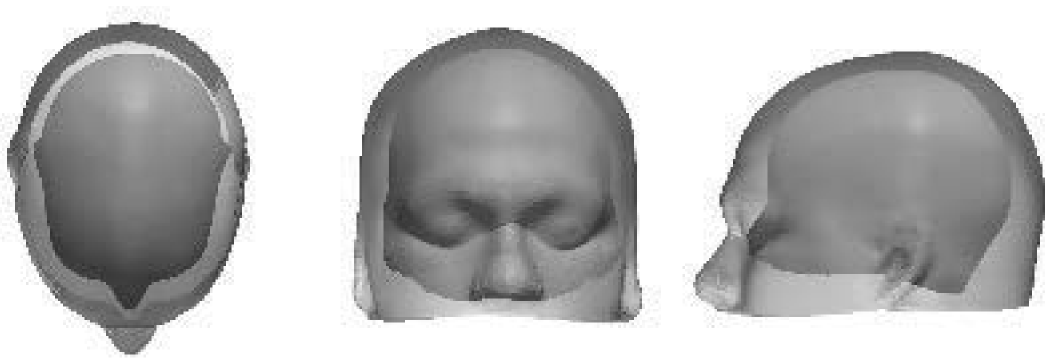

Figure 2. Mean head with first principal component added +3 and - 3 times standard deviation [7]

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

2 MATERIALS AND METHODS

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

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

3 RESULTS

3.1 Contribution from computer science

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

3.2 Contribution from computer applied engineering

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

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

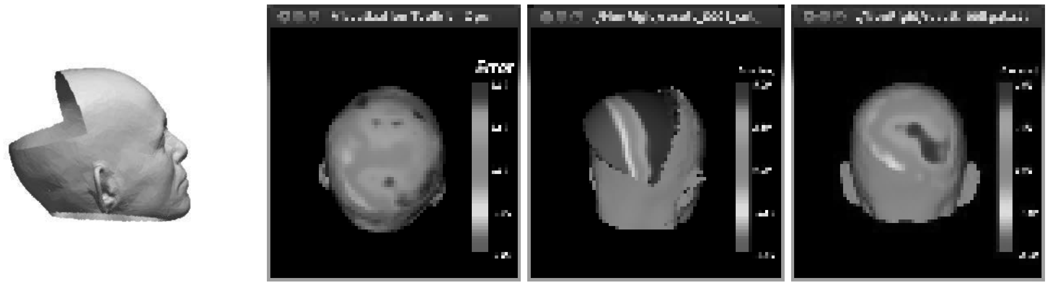

Figure 3. reconstruction of missing information in head shapes (left) with three shape reconstruction algorithms

3.3 Contribution from product development

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

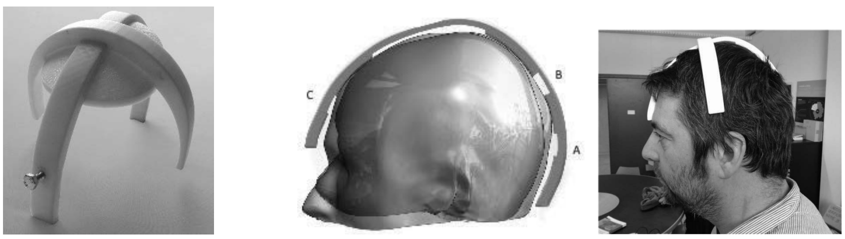

Figure 4. An instrument to measure variations on the human head (left) developed as a personalized design for and by the student, and points that were measured (middle right) by other subjects Stijn Verwulgen, right)

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

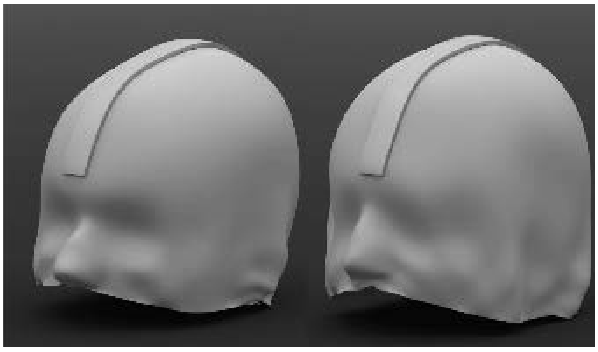

Figure 5. Personalized form following the models for the heads of Daniël Lacko and Stijn Verwulgen

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

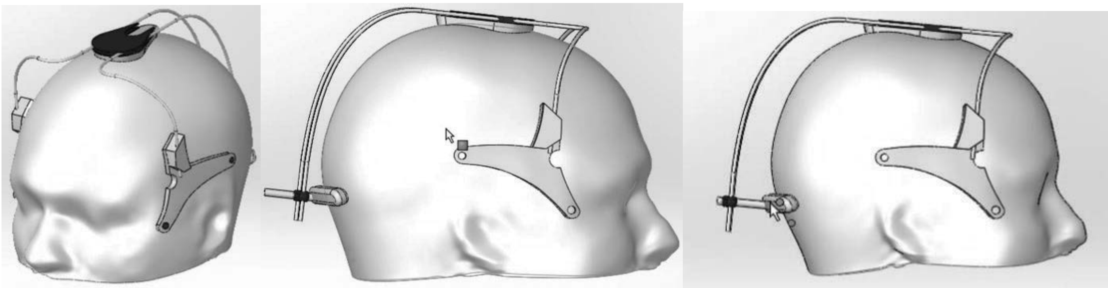

Figure 6. Demonstrator case of a personalized design

4 CONCLUSION

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

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

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

The student from Applied Engineering constructed an artefact removal algorithm that allows for an efficient automated reconstruction of original shapes, directly from medical images, thereby omitting labour intensive extraction of representative images by hand on an individual basis. The algorithm allows for an efficient extension of current statistical shape models concerning automated shape reconstruction and yields a promising approach towards automated acquisition of anthropometric measurements. She is now continuing her work in a PhD at the Vision Lab of the University of Antwerp.

The student from Product Development identified specifications for an enriched CAD environment based on statistical shape models. The current implementation was tested for design for additive manufacturing by the design of demos and verified with rapid prototyping, followed by recommendations for further improvements. He is currently employed in a paid internship in Spain.

These results clearly show the added value of interdisciplinary collaboration in education. Universities benefit from additional research projects, which might otherwise not have been realized. The industry benefits from clear applications and possibilities for further collaboration with universities. Finally, but perhaps most importantly, the students benefit from the broadening of their knowledge, get a first taste of different academic research fields and can add an ambitious project to their résumé.

The results of this project at master level have revealed the potential of a new design technique that has been further developed through research. Moreover the project serves another educational purpose: results have been presented to master students in product development, as an invitation to use the new technology in their design projects.

The authors therefore encourage other universities to employ master or even bachelor grade students for the integrated validation of research projects from different fields, with a focus on the development of new design techniques.

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APPLICATION OF VR TECHNOLOGY IN DESIGN EDUCATION

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

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

1 INTRODUCTION

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

2 AIM AND OBJECTIVE

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

3 VIRTUAL REALITY AND ALLIED SYSTEMS

3.1 Virtual Reality

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

3.2 Augmented Reality

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

3.3 Virtual Prototyping

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

4 APPLICATION OF VR AND AR IN DESIGN RELATED FIELDS

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

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

5 HAPTIC INTERACTION WITH VIRTUAL MODEL

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

Figure 1. Haptic interaction with Virtual model

6 APPLICATION OF HAPTIC FEEDBACK DEVICE AND VR IN DESIGN EDUCATION

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

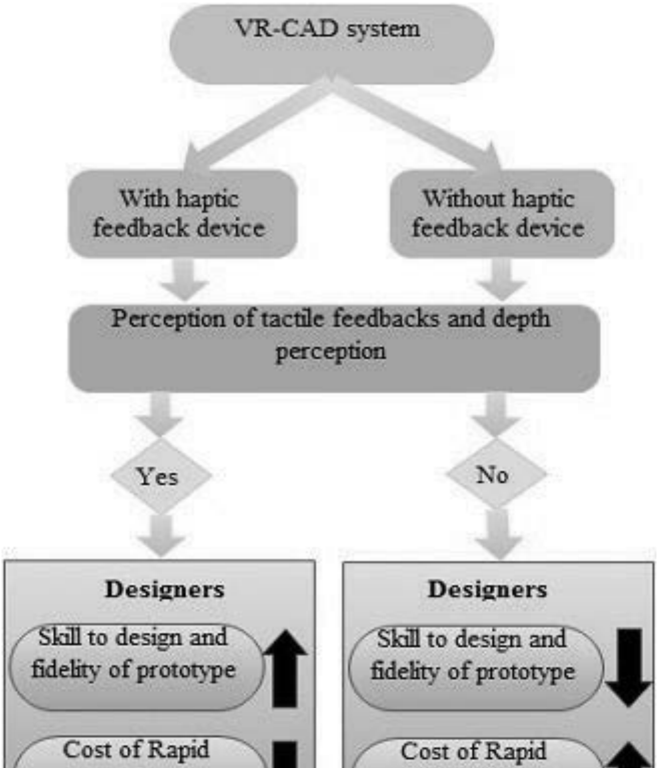

Figure 2. Flowchart the impact of VR with and without haptic on Prototyping

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

7 METHOD

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

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

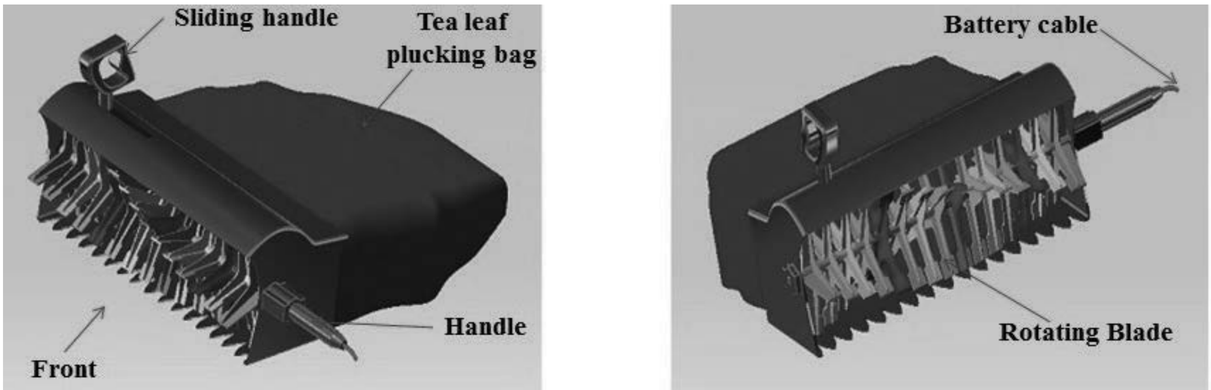

Figure 3. Battery operated Tea leaf plucking virtual model

8 SUMMARY AND CONCLUSION

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

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

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

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

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

1 INTRODUCTION

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

2 3D PRINTING

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

3 BACKGROUND

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

4 METHOD

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

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

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

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

Table 2. New set of guidelines

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

	can switch between using different input methods

5 FINDINGS

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

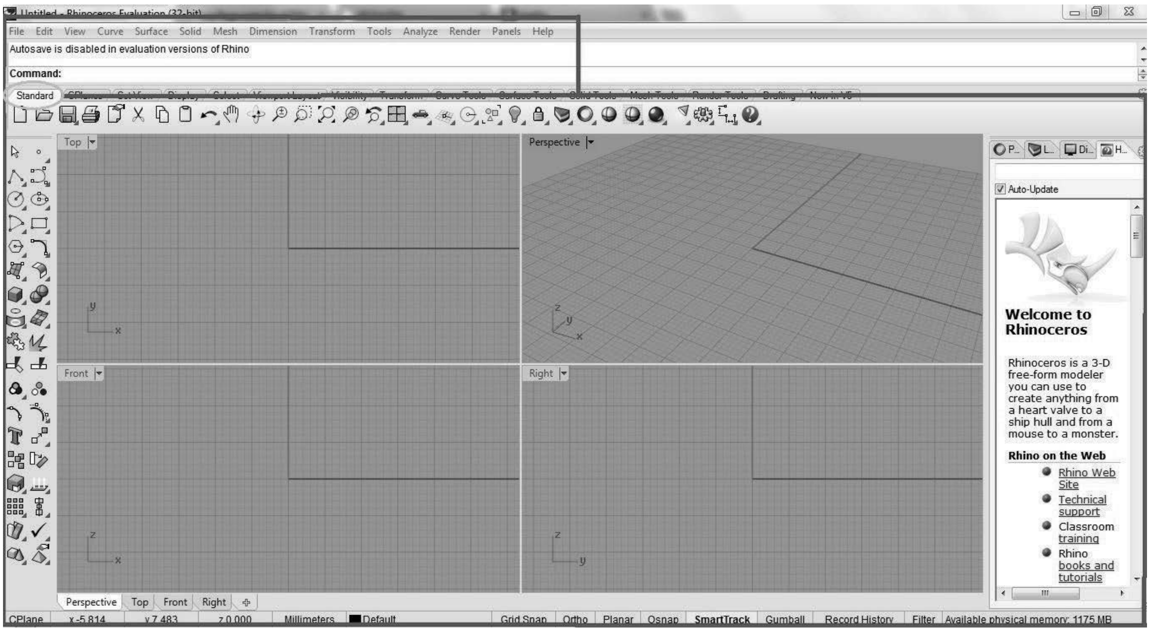

Figure 1. Screenshot Rhino desktop

5.1 The system should be simple and intuitive to use

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

5.2 The information should be perceptible to anyone

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

5.3 The system should be flexible and efficient to use

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

5.4 Error handling

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

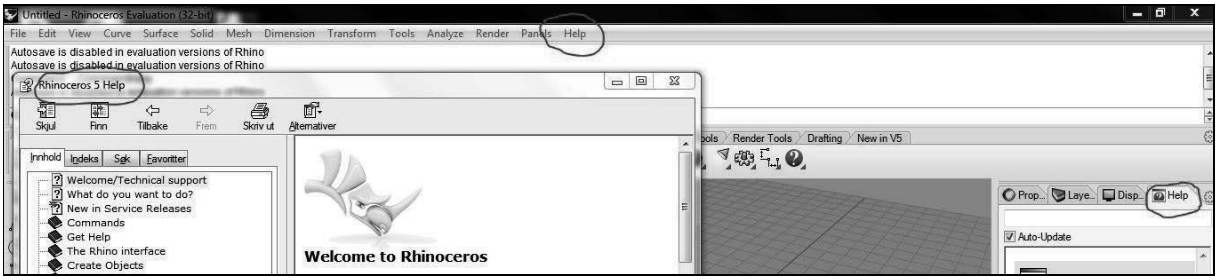

Figure 2. Screenshot of help options

5.5 Help and documentation

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

5.6 The system should be equitable in use

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

5.7 The system should demand minimum effort

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

6 CONLUSION AND FUTURE WORK

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

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