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TO LEARN TO DESIGN IS TO LEARN TO LEARN ABOUT POSSIBLE FUTURES: A LEARNING PERSPECTIVE ON DESIGN AND ITS IMPLICATIONS

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ABSTRACT
Design requires thoughtful application of methods to broaden one's understanding of the task and to generate alternative solutions. These activities imply learning. In an interaction design course for undergraduate engineering students, it was apparent that they put little effort into the usage of the design methodologies taught; nor did their choice of methods always appear to be thoughtful. To tackle this, we redesigned the course by applying a strategy based on sociocultural and experiential theories of learning and Marton's variation theory. The guiding hypothesis was that engineering students are essentially rational. The aim was not to steer them away from rationality, but to give them the means to develop the foundation of their rationality towards a design thinking approach. The major components of the course redesign were; changing individual project group supervision in short sessions to parallel supervision of several project groups in longer sessions, adding peer review of other students' work, and increasing the number of workshops and workshop-like exercises during supervision sessions. Since the redesign, student grades have improved, and the course evaluations indicate that they have gained more generic skills associated with design thinking. This highlights a crucial issue when teaching design to engineers: that of making design thinking appear rational. In essence, this implies teaching them *how to learn* about ill-defined problems rather than to learn specific methodologies. However, the experience of methodological variation in the right educational context can challenge and expand students' ways of thinking and thus constitute an essential base for their learning.

Keywords: Learning, design thinking, interaction design, engineering, bounded rationality

1 INTRODUCTION
Design requires thoughtful application of methods to broaden one's understanding of the task and to generate alternative solutions in the form of possible futures in relation to the task [1, 2]. These kinds of activities imply learning [3, 4]. In an interaction design course for undergraduate engineering students, we noticed that they put little effort into the usage of the design methodologies taught; nor did their choice of methods always appear to be thoughtful. Here, the term *thoughtful* refers to a critical, and when needed, an adaptive stance towards methodology and the design process as a whole [5]. These problems became especially apparent in the course projects and on the written exams. A concern related to this lack of methodological savviness was that it appeared as if the students did not always take the theory and methodology that was taught seriously and as a result, put little effort into studying the course material intended to constitute the foundation for their work on their course projects. Consequently, they had less hands-on experience of the methodology than intended. Less hands-on experience also implies fewer opportunities to reflect upon their experiences. Another related concern was that despite receiving plenty of formative feedback on both their project reports and from project supervision, the quality of the projects could still be subpar. Our interpretation was that the students sometimes used the feedback as an opportunity to probe the teacher about what was required for them to pass or receive a better grade, rather than as input that could lift their own learning and writing to a higher level. This indicates that the students applied a surface approach to learning [6]. A consequence of this is that they most likely do not push their own ability to the brink of

their zone of proximal development [7], but instead settle for *good enough*, which could very well be within their previous level of competence.

To tackle these issues, we redesigned the course by applying a strategy based on sociocultural and experiential theories of learning and Marton's variation theory [3, 4, 7]. A guiding hypothesis was that engineering students are essentially rational. They are to varying degree schooled to apply what Schön [8] calls a *technical rationality*. To become an engineer is to become a *rational problem solver*. Consequently, the problems engineering undergraduate students face are for the most part well-structured and have little resemblance to the ill-defined problems they face when forced to design for real users in real contexts. Thus, engineering students, at least early in their education, face problems where optimisation is not only the working strategy for problem solving, but also the best strategy. When facing real problems in a design context, they instead need to: 1) apply a *satisficing* approach to problem solving [9], and 2) learn how to question the boundaries of their own rationality in relation to the task as well as the boundaries of the task itself. Thus, we did not want to steer the students away from rationality, but rather to give them means to develop the foundation for their rationality in such a way that the design thinking approach appeared rational.

For these reasons, the aim of this study and the course redesign described below can be formulated as: 1) to help students see that the types of ill-defined problems that often appear in design require a different approach to rationality, 2) to better support student learning on how to apply design methodology in a more thoughtful manner, and 3) to help students reach higher levels of learning about interaction design in general. All this was to be done without having to utilise significantly more teaching resources.

2 THEORETICAL UNDERPINNINGS

2.1 Design and interaction design

Interaction design can be defined as "designing interactive products to support the way people communicate and interact…" [10, p. 9]. However, this gives little indication of what *design is*. There are several definitions of design. One of the most widely cited early definitions is Herbert Simons' [11]. Simon is concerned with the creation of artefacts, that is, the *artificial*. Artificial refers to everything that is synthesised by human beings, as opposed to the *natural*, which is the object of study for the natural sciences. Simon defines design as "...courses of action aimed at changing existing situations into preferred ones." [11, p. 111]. However, this definition says little about what the *designer actually does* and gives little guidance when it comes to how to approach the design process. Simon prescribes a scientific approach to design that focuses on problem solving, but also acknowledges that human rationality is essentially bounded. In other words, we are not capable of representing all the information that could possibly be relevant to make an informed choice nor do we have the cognitive computational power to make a fully informed choice either [11]. A main critique of Simon's approach, proposed by Schön, is that it requires "…well-formed instrumental problems to begin with" [8, p. 48], and thus overlooks the uncertainty and ill-defined problems typically associated with the early stages of a design process in particular. From Schön's perspective, design is closely associated with *reflection-in-action.* Hence, design can be seen as an iterative process of reflection-in-action "…on the construction of the problem, the strategies of action, or the model of the phenomena" [8, p. 79] and a reframing of the problem at hand. From this perspective, an iterative process of problem formulation and problem framing constitutes a crucial part of the design process, perhaps the most crucial. Consequently, the most important skills for the designer are those concerned with the (re)formulation and framing of the design problem. It also becomes clear that this problem formulation process cannot always be expected to be linear or definite.

Krippendorff [1, p. xv] goes even further in stating that "design is making sense of things". From this perspective, design becomes a matter of creating meaning, and the meaning of artefacts to their users and designers constitutes central parts of the artefacts design. For Krippendorff, meaning is not a stable entity, but is rather dependent on the context or discourse of use. This is true for both the artefacts produced and for the discourse of design itself. A central aspect is that the use of a product becomes its meaning [1, 12]. As we see it, the main issue for us as teachers is to enable engineering students to go from being solvers of well-formed problems approaching design in a primarily Simonian vein, towards becoming reflective practitioners who are also capable of questioning and making meaning in relation to the design task.

2.2 Perspectives on Learning

Learning can be defined as "a persisting change in human performance or performance potential" [13, p. 11]. Thus, when the designer in some way re-valuates or reframes the problem or reformulates the design task, his or her ability to perform in relation to it changes. This means that the designer has learned. Then, to become a good designer, the ability to learn in relation to the design tasks becomes central. Consequently, our main goal as teachers must be to provide course curricula and educational environments that help students develop their ability to learn in relation to the task. In practice, our course in interaction design and many other design-related courses for engineers contain several design methodologies intended to help students learn about the design task. These can include various methodologies for user studies, data analysis, idea generation (e.g., brainstorming), conceptual design, prototyping methodologies, and tools or methods that can be used to evaluate the design [10, 14, 15]. As pointed out in the introduction, it is not only a matter of knowing the methodology; the student also needs to learn how to apply it in a thoughtful manner. As we see it, though, some knowledge about different methodologies must come first, before one can expect the students to have the ability to apply them thoughtfully. We explain why in the following paragraphs.

In the next paragraph, we briefly introduce the relevant parts of the learning-related theories that informed our course redesign. In turn, we describe the backbone of the course curriculum – experiential learning – followed by Marton's variation theory of learning and Vygotsky's theory about the zone of proximal development.

According to the experiential theory of learning, all learning starts with the *concrete experience* of a phenomenon, followed by *reflective observation* through which the learner's understanding of the phenomenon is explored and new perspectives on it are introduced. These two steps of experiential learning are divergent in nature in the sense that the learners' perspective is widened. Thereafter, the learning process becomes convergent, that is, its focus becomes that of systemising the new perspectives discerned through what is called *abstract (re)conceptualisation*. This results in potentially new, actionable knowledge that can become the basis for *active experimentation*. Active experimentation results in new concrete experience and the process starts over [3]. In interaction design, concrete experience can be in the form of investigations of the design task or the attainment of information relevant for the task through field or user studies. Reflection upon these types of experiences in relation to the design task can then lead to a reconceptualisation or reframing of the task or of novel ideas regarding how to complete it.

The variation theory of learning "…points to variation as a necessary component in teaching in order for students to notice what is to be learned" [16, p. 559]. In order to learn about an object of learning, the student must perceive variation within the object. This implies that experiencing a problem or design task from several different perspectives or different instances of the problem or design task (such as experiencing the design task from the perspectives of different potential users), facilitates learning about it. As pointed out by Vygotsky, another important aspect of the learning environment is that it, together with the learner's intended tasks, match the learner's development level. Here, Vygotsky distinguishes between *the actual development level* and *the zone of proximal development* (ZPD). While the former represents the competence and knowledge the learner already has and can act upon, the latter refers to what the learner can achieve with guidance from more experienced supervisors or peers [7]. From Vygotsky's perspective, learning always occurs in the zone of proximal development, and as teachers, it becomes our job to ensure that students are challenged in such a way that they act within their individual ZPD. If students are faced with tasks that can be accomplished outside of their ZPD, that is, below their actual development level, then little learning will occur.

3 THE COURSE REDESIGN

In this section, we describe how we redesigned the interaction design course in relation to learning theory to meet the challenges presented in the introduction. However, before that we need to say something about the context. This course is just one of several that the students take in parallel as part of a *Master of Science in Engineering, Information and Communication Engineering Technologies*. The students also take a course on internet protocols and a programming course during the same study period. It should also be noted that the interaction design course is placed rather early in the programme, in the second year (undergraduate part) of a five-year educational programme.

As all the students were assigned the same course project in the interaction design course, the first step in the redesign was to supervise several groups in parallel in longer sessions instead of single group supervision in shorter sessions as was done previously. Secondly, we introduced student peer review of other students' project reports as formative feedback replacing the formative feedback from the supervisors. However, the supervisors continued to give feedback on what the students handed in for each supervision session. Thus, the students still received plenty of formative feedback on their projects. In line with previous research, we decided not to give teacher and student feedback on the same draft in order for the students to get the full benefit of the student feedback [17]. From a theoretical perspective, these changes enabled the students to perceive more variation because of the insights they gained into the other groups' perspectives on their projects. This included their problem interpretations, choice of methodology for user studies, idea generation, as well as how they went about drafting their reports [4]. It also offered them more opportunities to approach the task in an environment in which they had access to both teacher supervision and to potentially more experienced peers. Thus, this arrangement with big group supervision provided the students with an environment where they, at least theoretically, could realise their own learning potential in their ZPD in a more effective way than before with the shorter single group sessions [7]. By viewing the students as rational problem solvers, the redesigned environment was more capable of challenging the boundaries of their rationality. It did so by encouraging them to include other ideas in their reasoning and reflections about their design tasks that they previously might had not considered relevant or had had just failed to pay attention to. On a metacognitive level, such an environment can also provide insights into how the application of different perspectives and design methodologies contributes to learning about the design task.

Third, we increased the number of design methodology workshops, and fourth, we added workshop-like exercises to the supervision sessions. During the workshops, the students worked in groups with an isolated task rather than with a real design problem. This gave them an opportunity to receive formative feedback on their use of design methodology as well as experience in how other students approach the same problem. The latter meant that the students not only had more opportunities for experiential learning before they applied their knowledge to their own course projects [3], but also that the teachers had more opportunities to observe their learning and support them on their own individual levels in their ZPD [7]. The workshops can be considered as a first experiential learning loop, and the course project as adding more consecutive learning loops. This gave the students opportunities to reflect and develop their understanding of the methodology and theory before they applied it in their own course projects [3].

Fifth, more emphasis was placed on the need for the students to be familiar with different design methodologies. The project description was rewritten to state more explicitly, what was expected of them regarding the application of design methodology while still offering as much creative freedom as before when it came to the content of the course project. Previous research shows that freedom of choice within a well-defined structure is known to foster a deep approach to learning, while too much unstructured freedom can open up for a strategic or surface approach, especially when the students encounter conflicting demands or have insufficient time to study the course content properly [18]. Since the students' educational programme was designed in such a way that they usually take several courses at the same time, we considered conflicting demands and time constraints due to other courses as potential disturbances for them that had to be dealt with.

Sixth, we added a diagnostic test early in the course (week two of a ten-week course) on their knowledge of the design process and different design methodologies, including user studies, idea generation and data analysis methods. In order not to increase the teachers' examination burden, we decreased the length of the final written exam to compensate. The purpose of the diagnostic test was to ensure that the students came better theoretically prepared to their course projects as well as to ensure that they used the time scheduled for the course in the best possible manner. In practice, this meant that they got going with their studies directly when the course started, rather when the final exam was approaching.

3.1 Preliminary results

As of today, the course has been held three times in its new format. In both formats, students were graded on the following scale: 0 (fail), 3 to 5. Compared to the last time the course was held in its previous format, the student grade average has improved significantly, from 2.64 to 4.38 on the third time with the new format. However, one needs to take into consideration that the course design, including the examination format, has changed. Thus, it is hard to compare the results directly. In the course evaluations, students perceived an increased workload in the redesigned course. However, it still was moderate compared to the other courses this particular group of students attended. The required goals and standards of the course appeared to be clearer after the redesign, and the teaching was perceived to be significantly better. The most important difference in the course evaluations was that the *generic skills* obtained were perceived to be much greater. Generic skills refer to *problem solving skills, analytic skills,* ability to *work in groups* and confidence when tackling *new and unfamiliar problems*. The students also expressed appreciation for the big group supervision and the diagnostic test.

4 DISCUSSION AND CONCLUSION

In this study, we approach a crucial issue when teaching design to engineers: that of making design thinking appear rational to engineering students. In essence, this implies teaching them *how to learn* about ill-defined problems and possible futures in relation to those problems, rather than *to learn specific methodologies*. However, in order to learn how to learn, knowledge of different design methodologies can play an important role as they provide examples that help students to challenge their own rationality or, in other words, to break their own preconceptions of the design task. Valuable tools that can increase student learning of how such design methodologies can be applied in a thoughtful manner include; experiential learning, a learning environment that emphasises the students' abilities to perceive variation in how methods can be applied and how tasks can be interpreted, as well as opportunities to receive peer and teacher support attuned to their own personal levels of knowledge. These tools become even more valuable when successfully combined. The redesign of the interaction design course described above shows our attempt to combine these tools in a thoughtful manner in order to teach the students how a design thinking approach can be useful and rational for them. This is not the first-time learning theory has been applied to design. Hiort of Ornäs and Keitsch [19], for instance, report on how they integrated experiential learning into a student project as part of a design course. By doing so, they framed *design as learning*. This is a framing of the concept of design that is in line with Schön's [8] definition of design, which we agree with to a large degree. Although design as learning is one aspect of the topic of this study, the main aspect is its focus on the need *to learn how to learn*, that is, to learn how to facilitate one's own learning in order to make the learning that appears as part of the design process useful in relation to the design task.

It is worth highlighting that the results indicate that the students obtained more *generic skills* after the course redesign. The generic skills category, as operationalised in the course evaluation, refers to a number of skills that can be associated with design, namely improved capability to approach new and unfamiliar problems, analytic and problem-solving skills. As we see it, *design thinking is a generic skill* that transcends the boundaries of a particular task, like those formulated in a design course project. It is only when the students' skills can be applied in a more generic manner in a broader, less predefined setting that the application can be considered to be truly thoughtful [5]. Another striking result is that the students' results on the examination were much better after the redesign. Even though the redesigned course had a different format, making it difficult to compare to the results of the previous format, this nevertheless clearly indicates that the students' knowledge about interaction design had increased because of the redesign.

In this study we show how design can be framed as the capability to learn how to learn, and how this framing can be applied when teaching interaction design to engineers. The main point is that rather than trying to fight the strictly functional and rational approaches to problem solving that often are associated with engineering, we embrace them in our teaching and use them as a point of departure. In essence, this means that we have adapted our teaching to our student engineers in order to meet them in their ZPD [7]. We do not demand radical change from them, but through small steps we try to facilitate their development away from a strictly technical rationality [8], towards a design thinking approach.

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