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LEARNING ACTIVITIES THAT IMPROVE THE DESIGNERS SOCIAL SKILLS?

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1. Introduction

Bucciarelli [Bucciarelli 2002, pp.2-3] describes a conference event where the main speaker settled that US was a nation of technological illiterates, since less than 20 % knew how a telephone works. In what direction did the initial question – *do you know how your telephone works?* – nudge the respondents' answers? Bucciarelli found that the main speaker concluded the skills of the nation from merely a technological perspective, i.e., the physical device as such. Inspired by this, Bucciarelli, reflected on the question: *What does it mean to know how a telephone works?* Does the question imply knowing how to *use* it, how to dial local or long-distance numbers? One single perspective in the design and development of products cannot make the devices operate purposefully, so Bucciarelli concludes:

> Indeed, from my own observations, I can claim fairly confidently that there is no single individual alone who knows all the ingredients that constitute a telephone system work together to keep each of our phones functioning. There is no one "maker". Instead, inside each firm, there are different interest, perspectives, and responsibilities – corporate planning, engineering, research, production, marketing, servicing, managing – and consequently different ways in which the telephone "works.". [Bucciarelli 2002, p. 3]

As the quote above pinpoint, to make the telephone system work many expertise areas, inside, the firm, are involved in the design of it. But, also outside the firm, since the use of the word 'system' implies that a telephone needs the interaction of several other aspects to be designed to fulfil its objectives, e.g., infrastructure, operator services and users. Several solutions from several interacting firms build up contemporary products, as in the exemplified telephone system, and those products are from their users and customer's perspective seen in a more holistic way.

Defining products as mere technical solutions narrow the knowledge about how it works in the user context and how it fulfil user objectives, and subsequently, delimits knowledge for how to design it. Collaboration and teamwork in global product development is no longer an option - it is necessary for firms to offer purposeful products that fulfil user needs. However, complex relationships in, e.g., technical solutions, cross-organisational collaboration, heterogeneous teamwork and dynamic value chain constellations make contemporary product development even more complicated.

An on-going movement in manufacturing industry, which goes under the umbrella term Product-Service Systems (PSS), manifests the importance of multidisciplinary knowledge sharing particularly in early product development. In PSS, the device (the product) should be designed, developed, sold and used as a service. The last word in the term PSS – system – might indicate the idea of a systemic solution [Patnaik 2004], i.e., a solution which intertwined parts work together in a unified approach and meets basic and universal user needs. Meaning that, to develop PSS, the engineers have to dig deeper into the user context to find the golden nugget of such common needs to design for user perceived value. PSS is described as a specific type of value proposition [Tukker and Tischner 2006], and that value is judged by the users/customers in a far more encompassing way compared to standalone technical commodities. Besides a strong emphasis on sustainability issues, there is a high degree of innovativeness in PSS solutions to enable the creation of added customer value. Successful PSS development builds on long-term relationships with customers as well as partners, thus a productive collaborative product development process between all the PSS stakeholders is also anticipated.

Essentially, PSS acts as a trigger for changes in the established industrial ways of doing and thinking about technical product development where creativity, user interactions and sharing of experiences seem vital. The future co-workers in PSS development are trained in engineering education at universities. But, when the new paradigm is challenging the established traditions in product development, how is education adapted to support and ease the industrial changes?

The difficulties of stimulating learning of proficiency in creative work, user interaction and true collaboration have been a subject of discussion for a long time especially in engineer education. Still, today, the education of engineers has its emphasis on basic and specific technical knowledge, such as for example mathematics, physics, materials, manufacturing and production, meaning that "softer" interpersonal aspects, such as learning from users and heterogeneous team ideation, gains limited attention. In a worst case scenario, this is not trained at all. Our own university is no exception, and this paper intends to contribute to the challenge to apply both technical and "softer" issues, rather than an either/or perspective. Hence, applying PSS as a framework, this paper outlines a discussion to rethink learning activities [Biggs and Tang 2007] of engineering education. This is done to, in a near future, provide industry with freshmen possessing designing skills that are more suitable for systemic solutions within the PSS realm.

Firstly, the paper introduces a short description of the method. Secondly, the main part of the theoretical perspective are presented and discussed. Thirdly, the paper ends with some concluding implications for rethinking learning activities for engineering education.

2. Method

This paper builds on the authors' experiences in teaching activities for a Needfinding approach [Patnaik 2004] and in lecturing a creativity and product development processes view. Students from both mechanical engineering and industrial design participate in the courses. Understanding user/customers without initially suggesting solutions is in focus, and from that base design innovative product concepts. Typically, in a traditional project course the students are assigned with tasks that are as clear and concise as possible, for example they re-design a product or solve a specific mechanical problem. In the Needfinding/creative/process courses, the students are mostly assigned so called open-ended design tasks; this is done to avoid them to take an incremental design stance. The intention is to encourage them to not only solve a problem, but also to identify who the users are, what needs they might have and define the problematic situation that they perceive.

Tentative results from an experiment conducted in collaboration with undergraduate engineering students are used to exemplify teaching challenges. The experiment, its method and the result will be reported on in more detail in a forthcoming paper, thus this is not explicitly done here.

The theoretical perspective presented in this paper intends to show a difference from traditional product development. Thus, literature relevant for an additional perspective is chosen to provide a backbone for the discussions. This does not mean that the benefits of traditional product development are abandoned, on the contrary, it is fully acknowledged for the construction of the physical parts in a systemic solution.

Another delimitation of the paper is that it does not relate learning activities to the assessment task, i.e., how to grade the students efforts. Despite not being in focus here, this is a challenge in student projects directed towards open-ended tasks including a focus on "softer" more subjective and intangible lessons learned.

3. Teaching/learning activities and intended learning outcomes

Biggs and Tang [Biggs and Tang 2007] have coined two concepts to aid quality learning. The first concept is Teaching/Learning Activities (TLAs). TLAs should be designed with the purpose to encourage the students to generate understanding at a certain level. Due to the mutual relationship between teaching and learning, TLAs are suggested as a better term than “teaching method”, which could be interpreted as a one-sided relation. The second concept, advocated by Biggs and Tang [Biggs and Tang 2007] is Intended Learning Outcome (ILO). ILO describes what and how students are to learn and can be made at three levels:

- Institutional level – what the graduates are expected to be able to do
- Programme level – what the graduates of a specific programme should be able to do
- Course level – what the students should be able to do after completing a given course

The two concepts, TLAs and ILO, are interrelated and have an effect on each other. Thus, both concepts have to be considered to provide successful output when developing a course or a programme. TLAs should support the students to enact the ILO, these relationships are expressed as verbs, for example hypothesize, explain or elaborate. There is an alignment between what the students should know, i.e., the curriculum objectives, and how well they should know it, i.e., ILO. The formulation of the verbs is a key for teaching and learning, and also useful guidance in the course memo. Carefully specified verbs make it clear what TLAs that should be conducted [Biggs and Tang 2007].

The learning environment must be set up to fulfil a two-way approach. There is a difference of *nurturing* a learning activity (e.g., students practicing to drive a car) and *giving* lectures about a topic (teachers lecturing on car driving) [Biggs and Tang 2007]. Further, there are distinct preferences for how to learn.

3.1 Learning

In general, awareness of differences in student’s learning styles is proposed to make the learning situation more effective. Learning styles for how to assimilate theory could be described as opposites, for example; *deep processors vs. surface processors* [Mckeachie 1995], [Biggs and Tang 2007]. Deep processors can relate to a priori knowledge, thus possessing the necessary analytical skills which come from the capability to reflect on the subject. Surface processors lack such reflective skills, but can relate to theory by memorizing. Also, methods of teaching to enable learning are recommended to encompass many ways of displaying the subject at hand, for example to combine seeing, hearing and doing activities. Though, the education situation has to be dynamic and sensitive to changing circumstances, since individuals change learning styles in line with getting more experienced [Biggs and Tang 2007].

Experiential learning, coined by David A. Kolb, is a concept which has become used in two contrasting ways. One describes the learning that is undertaken by students, i.e., acquiring and applying knowledge, skills and feelings in an immediate and relevant setting [Smith 2001]. The other emphasise learning in the events of life where people themselves guides the efforts, thus teaching is not the sphere of sovereignty for educational institutions. Here, reflection is the core of the learning process and also explained as the common way of learning [Smith 2001]. Experiential learning is common in, for instance social work and field study programmes. In the early work of Kolb and his colleague Roger Fry, presented a learning style inventory encompassing converging, diverging, assimilating and accommodating styles [Smith 2001], see Table 1.

The gender perspective has gained increased interest from researchers, the fact that engineering education attracts few female students is evident in courses and, subsequently, in practice. Considering learning styles, it has been found that female students are more likely to consider factors related to the context of a design problem compared to male students [Kilgore et al. 2007]. The experiment did not guide the female students to act in a certain way, thus no such information were given or any encouragement were done to direct the females into a holistic management of the task. When conducting detail-level problem-solving of the design task there were no differences between the female and male approach [Kilgore et al. 2007]. Though, it was concluded that the holistic approach is more similar to skills needed in early stages of real industrial engineering projects. Accordingly, the study suggested that first-year women are more ready than men to do engineering in realistic settings, yet Kilgore et al. [Kilgore et al. 2007] conclude from their literature review that females are less likely to be recruited and retained.

Table 1. Learning styles (adapted from Kolb and Fry, source [Smith 2001])

Learning style	Learning characteristic	Description
Converger	Abstract conceptualization and active experimentation	• Strong in practical application of ideas • Can focus on hypo-deductive reasoning on specific problems • Unemotional • Has narrow interests
Diverger	Concrete experience and reflective	• Strong in imaginative ability • Good at generating ideas and seeing things from different perspective • Interest in people • Broad cultural interests
Assimilator	Abstract conceptualization and reflective observation	• Strong ability to create theoretical models • Excels in inductive reasoning • Concerned with abstract concepts rather than people
Accommodator	Concrete experience and active experimentation	• Greatest strength is doing things • More of a risk taker • Perform well when required to react to immediate circumstances • Solves problems intuitively

Besides learning styles, there are other aspects that are found as significant for how engineering design students learn, for example it is suggested that prior knowledge, intelligence and motivation are critical [Mckeachie 1995]. In particular, willingness to learn is vital for the learning process, i.e., not just focusing on tests and grades. Willingness is explained to depend on the students' intrinsic motivation for learning and that teachers can support such learning outcome by coaching the students, rather than communicating the contents of the subject at hand. In other words, teaching is more inspiring the students to develop their own learning processes, supporting them in developing appropriate skills and strategies for continuous learning [Mckeachie 1995].

3.2 Personal motivation

Students can be categorised into two motivational styles for learning, namely mastery- and performance oriented [Pintrich et al. 1993]. Students with a mastery orientation focus on understanding and/or discovering general principles underlying a problematic situation, e.g., explore the context for the sake of learning, or designing for the sake of improvement rather than competition. The performance-oriented students focus on obtaining good grades and perform well in competition, e.g., focus on a product's weakness and correct it to perform better in comparison to another.

However, in education and practice mastery is not always easily separable from, or superior to, performance orientation. Thus, in an experiment that the authors of this paper conducted, the two types of personal motivation were referred to as goal-oriented, since students were expected to show tendencies toward defining and accomplishing goals, and insight-oriented, since students were expected to pursue understanding of a problem's context in depth to generate and explore concepts. Successful design activities are depending on a multitude of factors. Some factors might be, for example, the social aspects of a design process, the degree of innovativeness desired, or the extent of satisfying the user need. The experiment was set up to, as far as possible, mirror such a realistic open-ended design situation. The focus in the experiment was to investigate how homogeneous teams approached the design assignment. Thus, the experiment did not only provide transparency for the actions the students took to solve the given task, but also how they approached the learning situation.

The students were divided into two homogeneous teams, one insight-oriented and one goal-oriented. A student's individual motivation was determined by using parts of the Motivated Strategies for Learning Questionnaire (MSLQ) [Pintrich et al. 1991]. By doing so, we ensured that either team would consist of students from the extremity of an orientation, and the analysis could then focus on the differences. The two types of personal motivation were expressed as two distinct operations. The insight-oriented team was starting by building up a holistic view of the task, the potential users and their context, but also they extended the focus to encompass stakeholders outside the firstly settled application area. The insight-oriented team emphasized understanding the task and learning about stakeholders and their needs, building gradually and iteratively to the definition of possible outcomes, thus this model was termed as problem-setting. These students showed a motivation to learn and become more knowledgeable about the problem, but had no personal need or profit interest in it.

The goal-oriented team was starting by explore the educational task and from that they agreed on a design intent. The team conducted actions to steer the task towards that early settled goal, thus this model was termed as problem-solving. Tentatively, the experiment shows some challenges for engineering education, since it can be expected that goal-oriented students need a clear course description, e.g., the teachers should provide a concise goal, and insight-oriented students need to explore the subject at hand, e.g., the teachers should act as a sounding board and provide prompt feedback. The tentative result indicates some implication in design practice, in the case of PSS development where the early stages should be explorative and investigate the context and user needs; insight-oriented people could perform better than goal-oriented. And, vice versa in the later stages goal-orientation is preferable.

3.3 Level of details

The abstraction level for engineering education is also a commonly discussed matter, for example how deeply should the context within which the designers are solving problems be understood [Kilgore et al. 2007].

PSS solutions tend to be more user-centred than traditional products. Thus, putting demands on the engineers to extend their knowledge areas beyond the technical function. This emphasises the importance of knowledge sharing across disciplines, where an analytical expertise in the traditional engineering domains could be a key. A vision for providing outstanding engineers is the philosophy to create T-shaped people [Winograd 2008]. T-shaped people are people that *"…maintain the depth and focus on a single discipline while adding a "crossbar" of design thinking that drives the integration of multiple perspectives into solving real problems."* [Winograd 2008, p.45]. A depth in the engineering design practice could for example be widened with a "crossbar" in understanding users and business savvy. Studies have found that senior designers were more capable to consider a broader scope than a freshman, and that seniors were more confident in managing ambiguity in design situations [Kilgore et al. 2007].

Based on these arguments, bringing in open-ended course assignments are beneficial for future design engineers to become more experienced in managing ill-defined problems. Also, providing learning opportunities to combine knowledge from different disciplines to benefit the design is one way to practice design thinking on different levels of abstractions.

4. A modern approach and new skills?

Solving a traditional product development problem is a complex and demanding task, nevertheless the process usually starts in well-defined and technical focused specifications. Such a design task might be doable to solve by applying engineering reasoning and logics. Commonly, there is an optimal solution. Systemic solutions, on the contrary, are ill-defined and demand invented solutions [Lewis 2009]. Commonly, optimization is out of scope and merely satisfying solutions can be found. Hypothetically, traditional product development start from a specification to increase the torque in the machine by 30 %, while systemic solutions like PSS could start from a user/customer perceived dilemma where the productivity has to be increased by 30 %.

Still, a resolution on conception and realization of artefacts is at the heart of engineering, and also in PSS systemic solutions from manufacturing firms. But, nowadays design thinking can be considered

to be the essence of the domain, due to the necessity of, in parallel, defining the design problem, the strategy and the relevant process. In addition to engineering knowledge, knowledge about design thinking methodology, principles and user involvement practices has to be included into a modern engineering design curriculum. Thus, also part of a design engineer's new social skills.
Engineering education could include the learning processes of [Lewis 2009]:

- *Problem solving* – that support breaking out of comfortable and/or known mental sets to see new possibilities.
- *Divergent thinking* – to provide a mind-set to find several solutions to ill-defined problems. Include the ability to: (1) generate a number of ideas, (2) generate unusual ideas, (3) produce a variety of ideas, and (4) being able to exaggerate ideas. These abilities support early planning and definition of the design problem.
- *Combination thinking* – to take remote associations into the task to synthesize, e.g., merging ideas into concepts.
- *Metaphorical thinking* – to characterize new situations by referencing to a familiar one, e.g., to build shared design visions.
- *Analogical thinking* – to map structural features from a base domain into a new target domain, e.g., to enable detail design.

A key assumption of systemic solutions for PSS is that the product development activities are on the one hand highly social and, hence is performed in and between members in dispersed teams. Following keywords give an impression of such engineering activities:

- User focused
- Relational
- Qualitative
- Knowledge creation and sharing (experiences, gut feeling etc.)

On the other hand, the product development activities for manufacturing firms' PSS solutions could also be described by these keywords:

- Cost driven
- Technical
- Quantitative
- Knowledge transfer and reuse (facts, measures etc.)

The early stages of product development include, e.g., planning, scoping and concept generation. Commonly, these are described as diverging activities with exploration of the market opportunity and selecting a candidate concept as core interests. Though, it is recommended that the design intent should be decide as early as possible, subsequent activities are hence converging to obtain relevant information for the candidate concept. If so, engineer designers seek to shorten the diverging and exploration activities, and user information only inform a delimited piece of early development. And, for systemic solutions/PSS such an approach is to jump into solutions, since there can be several candidate concepts that fulfils the user needs and that have to be assessed before deciding direction. Design thinking [Winograd 2008] advocates quick iterations of diverging activities to ensure user orientation and understanding of user context. Thus, a process for systemic solutions/PSS describes many more diverging/exploring stages compared to a traditional development process. If the learning styles, diverger or converger [Smith 2001] and the individual motivation of being insight-oriented or goal-oriented actually are preferred behaviours in engineering activities a consequence is that practicing fulfilling all styles is important. In realistic product development, human resources are allocated in a project and that project has to be executed across both diverging and converging stages.
In common, classroom practices for engineering design learners are proposed to connect students with the real world of practice, to solve real world problems, to engage in real product development project that meet real needs [Lewis 2009]. All in all, both teachers' and students' efforts should focus on developing their own design thinking.
A main challenge in engineering design learning is to support a multi-perspective stance in the planning, scoping and concept generation stages of a development process. One proposal to meet such quality in the learning process is to coach students to be active [Biggs and Tang 2007]. The teacher's

role is to act as a “knowledge broker” between the students and their learning environment. Though, preferred learning styles and personal motivation also include the teachers’ attitude, i.e., the learning environment’s two-way approach insists on learning of all actors. From a teacher’s perspective the progress of his/her own design thinking depends on both practicing and lecturing. Further, on a meta-level it could be possible to argue whether or not, design thinking is within reach for all people. Design thinking builds on a constructivist paradigm, conveying a view where knowledge and meaning are created in interaction between our experiences and ideas, as well as in interaction with other human beings. Reflection in practice, on theory and on learning process is vital to build design thinking capabilities and expertise. The traditional engineering knowledge domains build on positivistic principles, making it reasonable to view knowledge as facts that could be passed on to students. Subsequently, it makes sense for teachers to lecture about a topic in classroom. In a worst case, students take notes, memorize and repeat it at the examination.

5. Concluding remark

A trend among manufacturing firms to move toward systemic solutions as for example, the product-service integrated ones, set the framework for this paper discussing learning activities of engineering education. We have argued that future engineers need social skills due to being exposed to new types of problems and new types of teamwork. We assume that the development of successful PSS solutions rely on the design engineers’ capability to explore the users’ context and identify their goals will be a key.

One contribution of the paper is that it sheds light on those additional social skills future engineers have to develop if they should conduct PSS development. Also, the paper put some of the responsibilities on the education of engineers that it should provide design thinking, user orientation and a service integration approach. The education environment that has been discussed states a two-way learning process, where both lecturing and doing should be supported. Design learners have to be able to, as far as possible, interact with realistic problems and experience collaboration in mixed teams. A gentle suggestion from the argumentation in this paper could be that the learning activities for PSS situations should support learning outcomes on different abstraction levels. For example, engineering education should at the:

Organisational level:

- Implant a knowledge sharing approach
- Apply a value perspective in development activities

Project level:

- Make use of heterogeneous design thinking
- Apply relevant processes and models

Individual level:

- Make problem-setting and problem-solving tendencies operational
- Instil a “crossbar” stance in every-day work

Another contribution of the paper is based on the idea that engineering education, in particular experiential learning approaches, is not only conducted at universities, but also in industry, i.e., in events of life [Smith 2001]. If so, the suggestion made here could aid developing a PSS culture, thus support the first steps to realize it.

Intentionally, the paper describes learning situations for the purpose of supporting understanding of industrial PSS development already in an educational environment. In addition to educating engineering students’ skills of how to solve technical issues, also providing approaches to understand users and their needs is a key. Thereby, future engineers could be equipped to understand what kinds of user needs to address and what kinds of user defined functionalities that should underpin the long-termed PSS solution.

Suggestions for future studies within the field could be to, from a pedagogical perspective, address grading and examinations. The industrial practise in general, and PSS in particular, requires global and close cross-organizational collaboration; hence education has to include more exercises based on teamwork. If so, the issue of individual grading and examination will be a challenge. Further, our own research, which is based on an engineering design perspective, has the interest to make knowledge sharing between technology development and product development projects more effective. There is a growing interest within this area, which encourage future studies.

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