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LEARNING FOR PRODUCT INNOVATION ENGINEERING

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1. Introduction

Within engineering education, that is education that addresses the core technical competences of engineers, there are also efforts that particularly address product development processes. This part is usually called engineering *design* education, to clarify that its focus is on the design stage, i.e. the very early stages of product development, e.g. idea generation, evaluation and conceptualisation of products. Historically, the early efforts of integrated product development [Olsson 1985], [Andreasen and Hein 1987] set the importance of synthesis in the design stage as the activity where the product at hand was to be defined and settled, while also highlighting the importance of bringing information from production and manufacturing into the design stage. Hence, the approach suggested integration of all internal contributors to set the specification for the technical goods, which in subsequent activities should guide the engineers' design of the product.
Products are in traditional engineering literature typically described as *"discrete and manufactured goods"* (e.g. [Pugh 1991]). The contemporary opportunities in product development, for example inclusion of new technologies or packaging of the technical goods into a value offer, have made products too complex to be defined as a solitude solution. Most products have interrelations and interfaces with other solutions, which make users and customers define them in a more holistic way [Mello 2002]. For example, already in 1994, Bucciarelli concluded that even those who make a telephone do not know how it works. Before answering the question how a telephone works, the constraints and delimitation of the answer have to be found. Does such a question mean; how to use it, how to dial numbers on it or does it merely address the physical device? And, telephones today, i.e. mobile phones are much more than a 'calling device'. To make it work, to make it useful, the engineers have to consider and design much more than the device as such. And, the making of a useful product cannot be done without collaboration among several internal and external contributors, e.g. corporate planning, engineering, research, production, marketing, servicing and managing [Bucciarelli 1994]. So, what actually constitutes 'a product' has drastically changed the last decades, there are plentiful examples of manufacturing companies in different domains that have extended their core engineering activities to include both user participation and service infusion (e.g. [McAloone and Andreasen 2004], [Tukker and Tishner 2006], [Williams 2007]). By the same token, those industries need to incorporate user-oriented innovation into their development processes as a constant driving force to provide new value [Akasaka et al. 2011].
As a consequence of a diminishing product definition and a changing environment, engineering design education has to adapt to provide the engineers' with the appropriate competences. However, looking in the review mirror, we can find that this argument has been proposed by many researchers long

before us [McKim 1972], [Simon 1996], [Hubka and Eder 1996], [Lewis 2009], while as active lecturers in engineering design education we experience that little impact of those long-ago-proposals of innovation thinking is evident when meeting the engineering students. As novice lecturers, over 15 years ago, and well acquainted with product development theory, we anticipated that teaching engineering design, user orientation and innovation opportunity management would just be a matter of fine-tuning the engineers' existing knowledge. We were wrong. Early on we realised that one barrier for a change in engineering design education was how lecturers, including us, were teaching user orientation and the innovation subject, i.e. the activities were still guided by the product development tradition and focused the technical solution. By this, the students were not challenged to start thinking differently. Another barrier was that teaching itself was different from the typical engineering education, i.e. it was, in opposite to engineering education, mostly talking and very little doing. Talking in abstract terms of something ill-defined–as user needs and innovation are–had limited impact, and engineering students could easily discard those aspects as too fuzzy to incorporate as a skill, or as something that would never be useful in their professional mission. Today, most of the students that are practicing engineering design in companies, "confess" that they were also wrong.

This paper intends to describe and reflect on a shift in teaching activities and learning objectives. We do this for the purpose of inspiring lecturers and instructors to reconsider and redesign their own pedagogical approach by adjusting their efforts towards a modern engineering design education syllabus.

It should be noted that problem-based learning (PBL) is used as a metaphor for teaching and learning activities that seeks to inspire students' motivation for practically address innovation and user-orientation in engineering design. One implication of this delimitation is that the discussion is not aiming to contribute to research on PBL or similar, but to the education and teaching of behaviour in design processes.

2. Methodology

The empirical basis consists of the authors' experience from designing, teaching and reflecting on courses in creative methods, product innovation, innovation engineering and user oriented development. Data comes from different courses at different universities; a common denominator for the teaching is the topics of innovation and user-orientation by design thinking. Moreover, empirical data comes from research and research education within the broader topic of product innovation and innovation engineering. A teaching team approach has been used in the main part of the courses, meaning that lecturing has been executed of at least two teachers where one have acted as a fellow researcher. Reflection of the lecture has been done immediately after the class. In cases where lecturing has been done alone, a follow up reflection in the teaching team has been done at the first available time. Further, due to the emergent nature of the courses and teachers' own improved skills in the subject; the lectures have thus been constantly improved. The reflections have aided to improve the pedagogical approach, while the contents have remained fairly stable over time. After a few years of frustration (late 1990s) the longitudinal and purposeful generation of empirical data was initialised in early 2000. The teaching was mainly conducted with mechanical engineering students in a project course, but also in a distributed project course consisting of international students with different backgrounds (mechanical, industrial design engineering, industrial engineering management, etc.). Over time, specific courses in engineering design thinking (since 2006) and innovation engineering (since 2010) have been designed, given and improved. As a complement to reflection, i.e. introspective data generation, the students have given feedback on the main part of all lectures. The feedback approach originates from the direct collaboration with Stanford University and the ME310 course (2004-2007) and is called 'I like, I wish'. The method is a simple way to generate 'the voice of the students'. After each lecture the students are provided with two sticky notes, one for expressing what has been particularly interesting and useful for their own learning (I like), and one for expressing what improvements they need for their own learning (I wish). The feedback has been used to improve next course, but also in some cases to provide immediately adjustments of the next lecture to support better learning. The 'I like, I wish' approach provide possibilities to reference students' excerpts, but some of those have been reported on in previous publications (see for example [Ericson et al. 2009]).

Further, a user-oriented approach in student projects has been reported on in detail in previous publications (see for example [Ericson et al. 2007]) and also in industrial projects (see for example, [Bergström et al. 2008]). Empirical data is not evidently accounted for in this paper, but as it is inherent in our experiences it serves as a base for our description. The theoretical foundation outlined in the paper comes from pedagogics, engineering design, but also from user-oriented development and innovation engineering to offer insights into the teaching and learning activities and the intended learning outcomes [Biggs and Tang 2007].

3. Teaching/learning activities and intended learning outcomes

Biggs and Tang [2007] propose that instructors need to address the teaching/learning activities (TLAs) and intended learning outcomes (ILOs) to support the quality of students', but also their own, learning. As the concept of TLAs indicates, there is a mutual relationship between teaching and learning, and the concepts are suggested to replace the widely used term 'teaching method'. The term teaching method can be understood, and thus have an effect on the activities, as a one-sided conversation style in the classroom. That is, students are passively listening to the teacher instead of taking active part in the lecture; it also indicates that the teacher is the one possessing knowledge that can be directly transferred to students. ILOs are a concept that describes the '*what'* and the '*how'* students are to learn. ILOs can be described from three perspectives, i.e. what the students as individuals are expected to be able to do, what the students in the specific course should be able to do and what the students of a specific programme should be able to do [Biggs and Tang 2007]. The two concepts are interrelated, that is the TLAs should support the students to enact the ILOs. TLAs should be expressed as active verbs, for example, theorize, problematize, employ, analyse and simplify, to make the necessary teaching/learning clear. From our own experience and when discussing with colleagues, we have found that few engineering education courses apply an intentional and coherent approach when designing the course syllabus or course PM. One reason for that is that some basic courses are 'inherited', for example you are assigned to teach physics and you get the previous material from a colleague. Often there is very delimited time for course improvements, either because of other job tasks, or because of management is allocating too small budgets for it. Also, not that we are taking any examples from our colleagues, but there are teachers that just keep on doing the things they have always done, for example expressing the attitude that physics are based on natural laws and if they do not change, why should I?

3.1 Engineers' mind-set

An ideal engineer's knowledge is suggested to build upon two types of basic understanding, general knowledge and technical branch knowledge [Hubka and Eder 1996]. Courses that develop the general knowledge are in engineering education typically, e.g. mathematics and physics. There are researchers that suggest rethinking physics referencing to changes in the environment and society, but also to the fact that wider technical problem-solving skills will likely enrich a person's career ambitions almost independently of occupation [Wieman and Perkins 2005]. This type of expertise, i.e. having depth in one or two areas, but possessing the ability for novel and adaptive thinking in a wide array of areas, is anticipated to be one key competitive asset for the future workforce [Davies, Fidler and Gorbis 2011]. The new broader education is not a case of favouring new subjects at the expense of the basic general engineering knowledge, rather additional skills yield better-educated scientists and engineers [Wieman and Perkins 2005]. Many universities are struggling with the fact that students quit courses, and even completely leave their university studies before graduation. Studies have shown that those who complete a physical major have a higher ability to tolerate traditional teaching, and have less to do with their ability to learn [Wieman and Perkins 2005]. Traditional teaching includes lecturing students (cf. teaching method) and the students' assignments are of 'back-of-the-chapter-type homework', i.e. repeating the contents of the chapter and providing a short quantitative answer. Grades are also based on exams of the same type of problems [Wieman and Perkins 2005]. Repetition is useful in some cases, but it has been showed in a simple experiment that only 10 % of students could provide a correct answer, i.e. remembered what the teacher told them 15 minutes ago. The students could not perform any better even though the teacher was replaced with a nationally renowned lecturer.

Moreover, asking teachers to estimate the percentage of students providing right answers showed that the teachers overestimated the students' ability to provide the correct answer. Another simple test showed that students that were interviewed immediately when they came out of a lecture were unable to remember anything but the general topic. A critical point here is that the amount of new material that the teacher presents during a lecture is far more than a person can process, internalize and hence learn [Wieman and Perkins 2005]. One important outcome after a completed course or program is that the student has moved his or her competence from general knowledge into a more expert competence. To support such learning it is suggested that the teacher focuses on supporting *"the development of the student's mental organizational structure by addressing the "why" and not just the "what" of the subject"* [Wieman and Perkins 2005]. The organizational structure is built up around the factual knowledge of a certain subject, while addressing the 'why' enables new elements of thinking to be constructed to widen the thinking and experiences, cf. learning innovation process. Prior knowledge or existing structures can provide an inappropriate base for the new knowledge, hence teachers need to support and guide the student's active thinking [Wieman and Perkins 2005].
The following are suggested as a better and more effective approach to support students' active thinking [modified from Wieman and Perkins 2005]:

- Apply a research-based teaching approach; allow students to explore, investigate and gather data about the problem.
- Minimize cognitive load; link new material to what students already know, keep to the subject, and avoid digressions.
- Address the 'why' and not only the 'what' of the subject; creates awareness that learning is more than memorization and that the subject applies to more than one specific situation.
- Address the students' beliefs of the subject; make reasoning, sense making and reflection explicit in lectures, assignments and in exams.
- Plan for and allow social interaction in the lecture; apply peer-discussions, whole class discussions and provide feedback.
- Never ignore the students' starting point.

3.2 Engineers' abilities and characteristics

Besides the general and technical branch knowledge, Hubka and Eder [1996], suggest that the ideal engineers should possess the qualities of leadership, organization, creativity and mental flexibility. They also suggest personal characteristics like openness, enthusiasm, broad horizons and readiness for cooperation. The actual learning process for engineering design education is suggested to include possibilities for students to, for instance [Lewis 2009]:

- Break out of comfortable thinking and established mental sets.
- Generate unusual ideas.
- Make remote associations when merging ideas into concepts.
- Build shared design visions in teams.
- Map features from a base domain into a new target domain.

Early efforts suggest overlapping activities of engineering education, i.e. the engineering-science technical knowledge, and engineering design education, i.e. processes, methodologies, principles and practices [Fonczak 2001], [Dym et al. 2005]. Browsing through the curricula for engineering education programs, it can be questioned if such overlaps actually occur in practice. We know for sure that it is not evident in our own environments. In general, the first year allocates most of the time to mathematics and teaching of computer aided design tools, while product development is often just introduced as a separate course. The second year is based on more mathematics, while physics as a knowledge area dominates at the end. The third year is often addressing the application of the basic engineering knowledge, and the last year is typically designed to provide a specialisation. Moreover, formulations like *"analytical skills are trained to solve concrete problems"* often occur in the programs' descriptions. This is in opposite to real situations in contemporary manufacturing industry in which providing value has become even more evident the last decade (e.g. Rolls Royce concept 'power by the hour', [Harrison 2006]). Future challenges for industry are hence to also manage the ‘fuzzy’ problems, customer expressions and transdisciplinary projects. It has been clearly expressed from our industrial research partners (who employ national and international engineering students) that *“students learn specific disciplines, but not the collaboration in-between them”, “students are good at solving problems, but not capable to define and constrain open-ended ones”,* and that students tend to view other disciplines as *“nonsense”.*

The engineering education programs that we browsed through are generally concluded to provide ‘*a wide base*’, e.g. students can be employed as project leaders in manufacturing industry, consultants, researcher or experts at a government agency. The wide base thus seems to address the different occupational positions and specialisations, rather than the provision of wide knowledge areas. During the programs, students are often offered possibilities to chose some optional courses. Those can, broadly, be categorized as belonging to the engineering design area. Since such courses often are optional, they signal that such skills is also optional. From the quick review of engineering courses, abilities and personal traits, like mind-set, flexibility, innovation and creativity, are, seemingly, not trained purposefully. ‘Social’ and ‘softer’ engineering thinking skills are not visible or are not clearly expressed in the programs’ curricula, thus it can be assumed that they are not part of the course learning objectives, or that they are trained when executing general course subjects. Nevertheless, if applying a traditional way of teaching it could be argued that no ‘new thinking’ learning can occur [Dym et al. 2005]. In some cases student project courses are implemented to enable students to build up a practical, collaborative and wider knowledge base, but if built solely on engineering education tradition most of the collaborative, innovative and creative aspects of design behaviour are probably not intentionally addressed. Yet, there exists teaching and learning approaches that addresses a wider range of skills and training in an applied and practical way, i.e. have a potential to make the ‘fuzzy’ more concrete.

4. Problem-based learning

Johnson’s [2007] criticism of books that claim to offer ‘the art [of a subject] ’ is that they generally do not identify the features necessary to achieve artistry. She explains that artistry is attained through active integration of two capabilities, namely mastery and originality, and that artistry is critical when the design problem is characterised by, e.g. uniqueness, complexity, ambiguity and uncertainty. Mastery is explained to have a conservative nature and is developed in a specific discipline (cf. general engineering knowledge), while originality is described in terms of characteristics, e.g. openness, flexibility and creativity. Originality is concluded to be *“the route to invention and innovation and it is the fuel for progress”* [Johnson 2007, p. 16]. Drawing from Johnson’s arguments it make sense to state that if an engineer possesses the competence to combine *mastery*, i.e. the ability to apply developed knowledge from a specific domain, and *originality*, i.e. the ability to generate new knowledge in another, s/he is equipped with innovation skills. Such an argument is also in line with the idea of ‘T-shaped’ people, a concept that has been coined at Stanford’s product design education program. T-shaped engineers would then develop depth and focus of a specific knowledge domain, but be trained in adding a “crossbar” of design thinking. Design thinking is what sustains the ability to integrate multiple disciplines into the problem-solving activities [Winograd 2008].

The ability of transdisciplinarity and cognitive load management are put at the fore of the future workforce [Davies et al. 2011]. Transdisciplinarity is commonly described as including the highest complexity of integrated knowledge expertise (for example discussed by [Edeholt 2004]).

Transdisciplinarity can be viewed as a system where several disciplines need to collaborate on several levels, one such example is nanotechnology, which integrates molecular biology, biochemistry, protein chemistry and other disciplines [Davies et al. 2011]. Collaborating at this level means that it is important to have an established competence and depth within a specific knowledge domain, but curiosity and willingness to learn beyond formal education are stated as critical personal assets [Davies et al. 2011]. Cognitive load, as discussed above, should be avoided from instructors in the lectures, i.e. not include too many new concepts and not make too many parentheses, but outside the classroom, there is a *“world rich in information streams in multiple formats and from multiple devices”* [Davies et al., p. 12]. The future workforce therefore have to develop approaches to manage the cognitive load in real situations, not only in terms of how to use social media (ranking, tagging, filtering etcetera.), but also in terms of developing processes to manage information overload (too much peripheral information) and knowledge overload (too much details). In such a case, the engineering education has to address the capability to see, think and make sense of a holistic picture, and not only practicing how to breakdown a specific problem. Today, engineering education seems to still focus on educating expertise, and spend very little training of future workforce skills.

One educational approach that addresses the learning of contents (cf. a specific knowledge domain) while simultaneously engaging self-directed learning (cf. training of mental structures and thinking) is problem-based learning (PBL). PBL supports learning on complex problems, i.e. those that do not have one correct answer, but the problem must still be realistic and resonate with the students' experiences [Hmelo-Silver 2004]. Further, all types of problems are not good candidates of PBL. The role of the problem is to engage students to think aloud, to express their understanding and therby also to investigate their current state of knowledge, thus it has to be integrated and complex. Problems that contain features of multidisciplinarity (complementary disciplines), interdisciplinarity (the solution is beyond the obvious disciplines) and transdisciplinarity as described above [Edeholt 2004], have the potential to be supported by PBL [Hmelo-Silver 2004]. Goals for PBL are to aid students to develop skills to manage flexible knowledge, to effectively solve complex problems, to engage in self-directed learning, to collaborate and to become intrinsically motivated for life-long learning [Hmelo-Silver 2004].

PBL, which can be seen as one of a family of experiential approaches, are not new in classrooms, it has a long history particularly from medicine education [Hmelo-Silver 2004]. Over time there have been many researchers that have compared a conventional curricula and PBL, yet it is still important to discuss this special way of learning [Schmidt et al. 2011]. The problem-based learning is a cyclic way of approaching a problem scenario, and, shortly, the activities aim to identify facts (cf. mastery), formulate and analyse the problem scenario to generate understanding of it, identifying knowledge gaps, search for and apply new knowledge (cf. originality) and by abstraction evaluate if the identified facts still are valid [Hmelo-Silver 2004]. The students are suggested to use a whiteboard, or a similar visual tool, to structure the knowledge and to aid the development of their own process, for example separating between facts, ideas, learning issues and actions [Hmelo-Silver 2004].

A person's pre-knowledge, i.e. the coding key that supports the build up of new knowledge, is part of the mental organisational structure and it can be valid or inappropriate for the new situation. Commonly, in such a case pedagogics not only talk about learning, but also stresses learning *anew* [Biggs and Tang 2007]. PBL sustains a cumulative learning process; meaning that it addresses what has been learned previously and provides support to also learn anew [Schmidt et al. 2011]. In that sense, PBL can be seen as a phased process starting in an investigation of prior knowledge, going through the phases of facilitated analysis of the problem that sets the base for the self-directed learning, in-between activities are reporting of findings and presentations.

A conceptual model of PBL is presented in Figure 1, starting from a scenario, topic, theme or similar, e.g. an open-ended problem situation, students frame and formulate a problem scenario for further investigation. Framed by that described and constrained scenario they structure and plan their activities, present their chosen scenario and get feedback before executing the task to learn more. After the self-directed learning assignment, students present their findings and get feedback before presenting their achievements for how to solve the chosen problem. The essential learning activities are the base in all types of education, where, for example, an exam or similar typically follows on the learning stage as the very last assignment. However, the possibilities for students to frame and define the initial problem scenario themselves and the last steps, i.e. reflection, evaluation and abstraction, are not that common in traditional teaching. Those steps intend to sustain an insight-oriented approach in which the new knowledge is set into a wider context, consequently could also provide input to either the scenario at hand or into another scenario. The evaluation, reflective and abstraction stages addresses issues of what have been learned, and examples of questions are; *"Does this fit all cases, if so why and why not?"*, *"What makes the knowledge suitable for one case and not for another?"*, *"How can the knowledge be generalised?"* and *"How can the process be adjusted to support the group to learn?"*. In engineering design education it is critical that the teacher supports the students to separate between the problem-solving of the technical issues and the learning process as such when reflecting and evaluating. Hence, teachers have to be present and supportive in the last stages also. As implied in the discussion, the learning in PBL is a result from both group collaboration and individual knowledge acquisition, indicating that the instructor's role is different from lecturing, but also that the teacher him- or herself is a learner [Hmelo-Silver 2004].

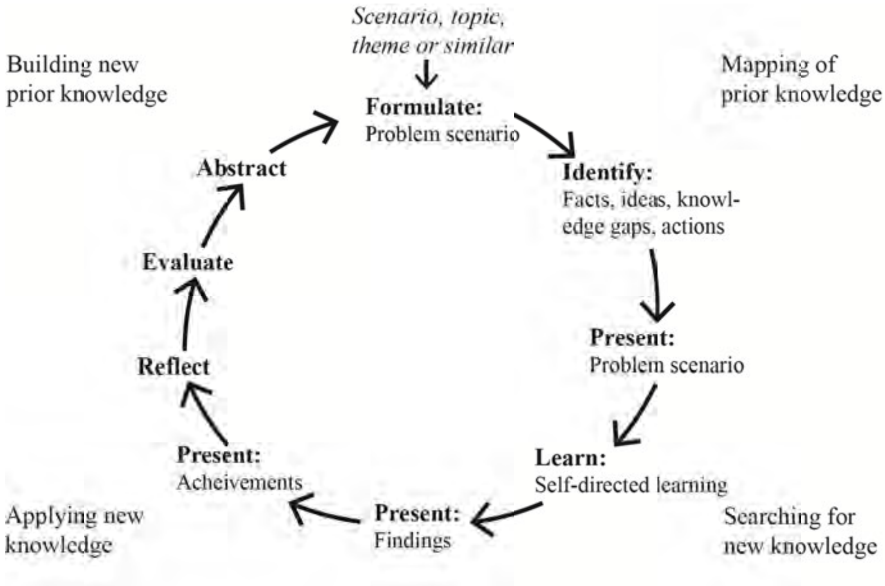

Figure 1. PBL cycle (Inspiration from [Hmelo-Silver 2004], [Schmidt et al. 2011])

4.1 Research based approach

Tutorials in engineering design education that are based on PBL or similar should, as stated above, guide students through both a problem-setting and a problem-solving process. Further, learning in PBL is overlapping activities of group collaboration and isolated individual knowledge acquisition [Schmidt et al. 2011]. In the same vein, the instructor's role is to, for example, facilitate the learning process and to coach the students' motivation for collaborative and individual learning. In this context, we usually make a distinction between the role of a 'facilitator' and the one of a 'moderator'. The latter role has some stakes in content, e.g. supports the group to discuss a specific matter or directs the search towards a specific knowledge area. The previous role specifically addresses the group process or the individual motivation for learning, e.g. supports equal communication and thinking together or encourage individual efforts and curiosity. Consequently, the instructor do not always need to possess expertise in the engineering disciplines as long as s/he has good facilitation qualities and a pedagogical approach that back up the teaching activities. Moreover, instructors acting in the role of a facilitator use listening and asking open-ended questions as primary tools, rather than tutoring from the lectern. Assigning guest lecturers and/or access to other teachers will sustain students' access to expertise, but students develop a more self-directed learning over time. PBL should also encourage students to discuss peer-to-peer and share experiences across individuals and groups. Based on these features, PBL teaching has similarities with a research based approach, e.g. supporting exploration, investigation, analysis and synthesis. It has been found that students when encountering PBL the first times do not search knowledge beyond what they have decided in the mapping activities in the beginning, but the intrinsic motivation increases when becoming more acquainted with the PBL rationale. Over time students become committed to search for new knowledge in libraries [Schmidt et al. 2011], Internet and by using other sources. One important implication of this is that PBL or similar approaches cannot be evaluated on a one-time basis.

Traditional teaching has, as discussed earlier in this paper, a tendency to become frontloaded and thereby creating cognitive overload [Wieman and Perkins 2005]. This 'hard' scaffolding of knowledge is not apt to support self-directed learning, instead lectures and knowledge should be provided on a 'just-in-time' basis [Schmidt et al. 2011]. Just-in-time means that the 'bulk' of knowledge is given in portions and not as a package in the beginning, i.e. the lecturing is customized to support each group or individual depending on where in the PBL exploration process they currently are. This implies that lecturing should be evenly distributed and follows the students' progress, rather than following a rigid agenda. Though, students have expressed that they wish:

…"that the lectures have more information from the textbook".
…"we had more background".
…"more theory".

One implication of providing knowledge, i.e. lecturing about theory from literature, on a just-in-time basis is that students cannot recognize that they are given the same amount of 'lectures' when they are provided in a direct and embedded way. Further, students change their behaviour over time and become more self-directed, so the facilitator's role as a prime source of information fades out. This implies that lecturing after a while is more focused on monitoring the group and making moment-to-moment decisions about how to support the students' learning processes [Hmelo-Silver 2004]. From a student point of view, visual assessment of the teacher's efforts as if doing traditional lectures is no longer possible, but in hindsight they recognize that they like:

…"the creative parts where you have to think. Makes knowledge deeper".
…"that we got the chance to use the theory".
…"that it is fun to do something practical".

PBL puts high expectations on the teacher's capability to be responsive to the students' needs and how to adjust and manage a dynamic planning of lectures. PBL is not, as some might think, a laid-back approach to teaching, instead it is a fairly demanding task involving continuous improvements (cf. the teacher is also a learner).

5. Practicing new engineering design skills

It can from a critical, also self-critical, point of view be questioned if engineering education merely addresses the mastery of technical knowledge, i.e. what Johnson [2007] exemplifies with a paint-by-numbers kit for a painter. If so, such education maintains a 'business-as-usual' approach and not the important change in design behaviour to support the future state of innovation leading companies. Companies ask for new employees that can, for instance, not only execute a mission but also cope with ambiguity and uncertain information in order to adjust existing methods, tools or processes to the new situation, and they ask for engineers that are well acquainted with the technical knowledge domain, but also capable to communicate and contribute with their expertise across several disciplines. Bluntly, the engineering skills and the engineering design skills are in industrial practices packaged and intertwined, while it can be argued that they are clearly separated in education. Changes in product development models, for example going from a product-oriented one to a service-oriented, and changes in selling, for example going from selling stand-alone products to mass-customization hence open up the design process for user participation, are two grand challenges that company representatives express. This exemplifies that the engineering activities imply more agile approaches of product development.

The paper set off from the intention to describe and discuss a shift in teaching activities and learning objectives for the purpose to inspire a change that could adjust to a modern engineering design education syllabus. As discussed in this paper, acting in a business environment with changing conditions and circumstances put some expectations on changes in the skills of new employees, and thus students. Also, it has been argued that a change in basic 'contents' is not a key issue for the syllabus, but rather a change in how the contents is trained and internalized in the students learning processes. The PBL metaphor has showed that students solving a complex engineering problem can also, if facilitated, be fostered in innovation and engineering design thinking. Some suggestions and considerations can be made.

- Any change comes with a lot of pain and often you cannot suggest a big leap, unless being in a very critical state. Start the change at levels, which already include a more self-directed type of learning, e.g. master thesis work or student project courses. Proceed to change courses and to base new courses on PBL approaches, before starting new programs. Future programs should include parallel and integrated work across disciplines, and such a structural change must be supported of top management because a structural change insist, not only on passionate, but also on authorised support.

- Do not underestimate the importance to redesigning ILOs, TLAs and align the activities according to them.
- A change in teaching and learning inspires other changes, for example some classrooms might need to be redesigned, for example to support swift changes from individual to groups exercises or to support just-in-time lecturing.
- Allocate time, resources and formats for self-assessments. PBL can also be adjusted to support the organisation to learn anew.

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