DESIGN OF LEARNING ARTEFACTS
-PROTOTYPING CHANGE OF EDUCATIONAL CULTURE

Åsa Wikberg Nilsson & Oskar Gedda
Luleå University of Technology

ABSTRACT
The overall objective of this paper is to contribute with knowledge of how learning artefacts can support both students, in taking more informed actions in becoming a professional engineer, and teachers, in design of relevant teaching and learning activities. This study is done as part of an on-going CDIO implementation, involvung change of educational culture for leaders, teachers and students. For leaders and teachers, this involves a challenge to convert the CDIO intentions, into practical tools and everyday teaching and learning activities that in the end have only one overall objective: to support student learning. The current study included prototyping the learning artefact 'IDE competence profile' in teaching and learning activities and exploring how this contributed in strengthening students' self-awareness of professional ID engineer identity, and in both students and teachers taking more informed actions during an introductory program course. The learning artefact contributed to teachers' and students' understanding of the professional ID engineering role, and also to more informed, self-directed actions during the course. In this paper we propose that learning artefacts not only support students' self-awareness and guide their actions, but also help teachers in creating learning experiences that contribute to students' understanding of the professional engineering role and thereby contributing in taking steps for change of the educational culture.

KEYWORDS
Strategic pedagogic development, artefacts, self-regulated learning, competences, objects of learning, professional role, CDIO standards 1-4

INTRODUCTION
The focus of this paper is learning artefacts, intended to support self-regulated learning strategies, towards personal, interpersonal and system building competences. In Sweden, programme objectives stated on a national level intend to steer higher education through directing its outcomes. However, a starting point in this paper is that policy descriptions such as formal programme objectives has weak manifestation in teaching practices, and thus fail to support teacher and student daily activities. An answer to this might be to establish clear measurable criteria, which restricts teachers' or students' influence and authority. A contrasting view is that programme objectives outlined at a national level neither can capture the complexity that exists in terms of conditions and realization in a teaching and learning practice, nor can they support or guide teacher and students' activities (Wernberg, 2009). Gedda (2014) for example found that students easily could describe a course they had performed, but had much more difficulty in describing what they were learning through participating in a learning activity, or what they had learned

after the course. For this reason, links between intended learning outcomes, and actual learnings can be said to not be prominent. There is hence a challenge to re-think the intent of a program in such ways that it can guide the teaching and learning practice. Intended learning outcomes in higher education can also be defined as *intentions*, intended objects of learning, learning *opportunities* such as activities and assignments that constitutes the enacted objects of learning, and *outcomes,* what students actually learn, as the lived objects of learning (Wernberg, 2009). In our view, the differences is that intentions often are formulated as ILOs students should demonstrate, which may be judged as right or wrong, whereas actual understanding is created within a context, a learning space, in which both students and teachers enact the learning experience. In the current study we explore how learning artefacts can guide enacted objects of learning, and support Industrial design engineering (IDE) students in becoming professional engineers. Drawing on theories of strategic pedagogical development, self-regulated learning and design of artefacts, we in this paper describe the design and implementation of a learning artefact, with the intent to support both students' learning strategies and teachers' teaching practices, as well as the intentions of CDIO.

SELF-REGULATED LEARNING

One of the most fundamental questions in higher education deals with how students learn and become skilled professionals. One aspect of this is described as strategies of surface vs. deep approach to learning (c.f. Marton & Säljö, 1976). This can be summarized as *reproducing* vs. *understanding* materials. Such learning strategies are not individual constructions, but depends on both students' and teachers' prior experiences that contributes to a educational culture, that is, how the student interprets requirements and answers to the perceived meanings in the learning environment (Gibbs, Knapper & Piccinin, 2009; Prosser & Trigwell, 1999). Self-regulated learning can exist with different strategies, but influence, as we understand it, not necessarily the quality of learning. However, Gibbs et al. state that an educational culture that favours students developing their own meanings, are more likely to result in higher quality of learning. Self-regulated learning should not only be the student's responsibility, as it involves how teachers interact with students in learning activities and influence how education is organized and operated (Zimmerman, 1990). In this perspective, the focus should shift from analysing an individual student's learning ability, to what can support students' developing independent learning strategies in form of e.g. feedback, motivation, personal responsibility and self-awareness of academic achievements. Self-regulating students, in contrast to some of their peers, actively seek information about what is required to do and learn to master a task or a subject. When they face challenges, such as confused teachers, difficult concepts or texts, or other more or less poor study conditions, they will find a way to get the job done. Self-regulating students learn through a fairly systematic and controlled learning process, because they acknowledge that their performance is worth the effort (Pressley, Borkwski & Schneider, 1989). The strategies that self-regulating students adopt support them in setting goals and continuously self-evaluate their performance, giving them greater opportunity to control their learning progression, compared to those students that doesn't adopt such strategies (Zimmerman, 1990). In line with this is Osberg and

Biesta's (2008) argument of an alternative to the dichotomy of "unguided learning" versus "planned inculturation" in the concept of 'space of emergence'. This involves to allow space for explorations of intentions, through representations and actions. It requires an educational culture enabling teachers and students to take own initiative and discuss each other's understanding and expressions. Such space of emergence contributes in promoting self-regulated learning through an active engagement in meaningful discussions, rather than promoting meaning transfer from teacher to student. This is supported through an understanding of professional qualifications, support for self-evaluation, encouragement of dialogues between teachers and students, contributions to motivation and self-esteem, and to continually provide opportunities for high-quality feedback (Hattie, 2008). When teachers provide feedback to students, they should in Osberg and Biesta's view be ready to flexibly interpret student use of resources: what they have thought and acted on, rather than judging a specific outcome as right or wrong. In such educational cultures, it is more likely that students' experience a return on investment, and that they can adopt self-regulated learning strategies. In up-coming sections, we discuss design of learning artefacts to support self-regulated learning.

DESIGN OF LEARNING ARTEFACTS

In general, the concept of artefacts can be described as objects that are intentionally designed. In a teaching practice there are a variety of designed artefacts such as whiteboards and projection screens. Objects designed to support a learning activity, i.e. with the intention of guiding students discussion or actions in certain ways, can be described as learning artefacts. A relevant question in this respect can therefore be how artefacts can be designed to enhance learning. Ideally artefacts are objects that embodies designers' contextual knowledge and experience, resulting in value-creating solutions. Ehn (2008) for example describes that artefacts can be seen both as *products* that provide users with solutions to needs and access to certain features, and as *things* that contributes in change of user behaviour and thus opens up new ways of thinking and acting. In this view, a central part in the design of an artefact is to create connections, so-called *alignments*, which support a specific intended use, but also opens up completely new ways of thinking and acting. Artefact's ability to support alignment in a teaching and learning practice is what interests us in the current learning experiment. A challenge in design of artefacts for learning is however that they actually are implemented and used. Cuban (1986) for example argues that no matter how important an object, a tool, a particular technique or intervention may seem, teachers must see the value and how it can support them or their students, otherwise the artefact may never be meaningfully implemented and used. Artefacts can be affordances to action, i.e. support meaningful discussions of the overall learning objectives and/or possible actions to take, but they might as well limit the scope if they are not experienced as meaningful (e.g. Wenger, 2008; Trowler, 2008). Affordance is for this reason created in the activities in which the artefact is used or discussed, when the artefact supports or realizes the participant's intentions. Trowler (2008) for example describes that artefacts can be imbued with skills, means to reach certain goals, which means that students' overall performance with the artefact improves, whether or not there is any other change in the individual ability. Such artefacts should be designed to be able to be abstracted from a particular context, and be able to move between different practices, and yet be interpreted for practical use. This can be labelled as a 'boundary object' (Star & Grisemeier, 1989; Bowker & Star, 1999; Star, 2010), which are intended to help increase the capacity of an idea, theory or practice, by exceeding culturally defined boundaries, such as support in and between knowledge areas and/or toward the current teaching and learning practice. A boundary object does not necessarily mean consensus in the teaching and learning practice, Star (2010) emphasizes that boundary objects should contribute to coordination and direction, without necessary stating what to do, allowing a user to interpret his or her own understanding from the local practice, which in turn can be reinterpreted in a larger collective activity between practitioners. Boundary objects allow different practices to be linked together, as individuals and groups can reach mutual understanding on a common task, without being forced to agree on how it should be performed (Wenger, 2008). A learning artefact that support an overall understanding of the main educational objectives, can be used by teachers and students in different ways, while their performance still improves.

THE IDE LEARNING EXPERIMENT

Until now in this text, we have laid the foundation and presented some tools with the aim of better understanding how intentions can be built into learning artefacts, be perceived as less abstract, and support meaningful interactions between students, teachers and educational leaders. The following sections includes an overview of the IDE learning experiment, outlined as how the learning artefact was conceived, designed and implemented, and how we plan to operate its use.

CONCIEVE

The context of the current study is an on-going CDIO implementation at Luleå University of Technology (LTU), Sweden, in which Industrial Design Engineering (IDE) is one of the pilot programs. Before the current CDIO implementation, students perceived the courses in the IDE program as separate parts without relating to the IDE context, and without a constructively aligned curriculum. For this reason, several activities were initiated, among them educating teachers in CDIO standards, as well as discussions of the intent of the IDE education, and how teaching and learning activities better could contribute to the intentions of CDIO. A result of these preliminary activities was the development of a 15 credits introductory course during the first semester. The course was set-up for the around 80-90 first year IDE students, from different backgrounds, experience, age, and from various residencies in Sweden. The difference between upper secondary education and higher education is for some of these students huge, and it is quite common that the first university semester includes a search of identity in the IDE context. The course should be teaching effective, and relevant and inspirational to students, retaining them in the IDE program and profession. This however required a transformation of the educational culture, from the idea of one course - one teacher, with his or her own idea of the contribution it would provide to students' learning, into what is described as "an integrated approach of identifying students' learning needs and construct a sequence of learning experiences to meet them" (Crawley et al., 2014).

DESIGN

A preliminary study, consisting of interviews, focus groups and discussions with both educational leaders, teachers and students at the program, indicated a need to support the understanding of both the IDE professional context and the CDIO approach. This resulted in the design of the artefact '*competence profile*', developed in a sequence of iterative steps through participation of teachers, students, and alumni. The artefact is in itself a visualisation of eight central IDE competencies, including a scale from 1-5 illustrating progression of each competence (see Wikberg Nilsson & Törlind, 2016). In the introductory course, specific learning activities were developed, including activities intended to explore the IDE profession-specific knowledge and the characteristics of personal, interpersonal, and product, process, and system building skills needed for an ID engineer, see figure 1.

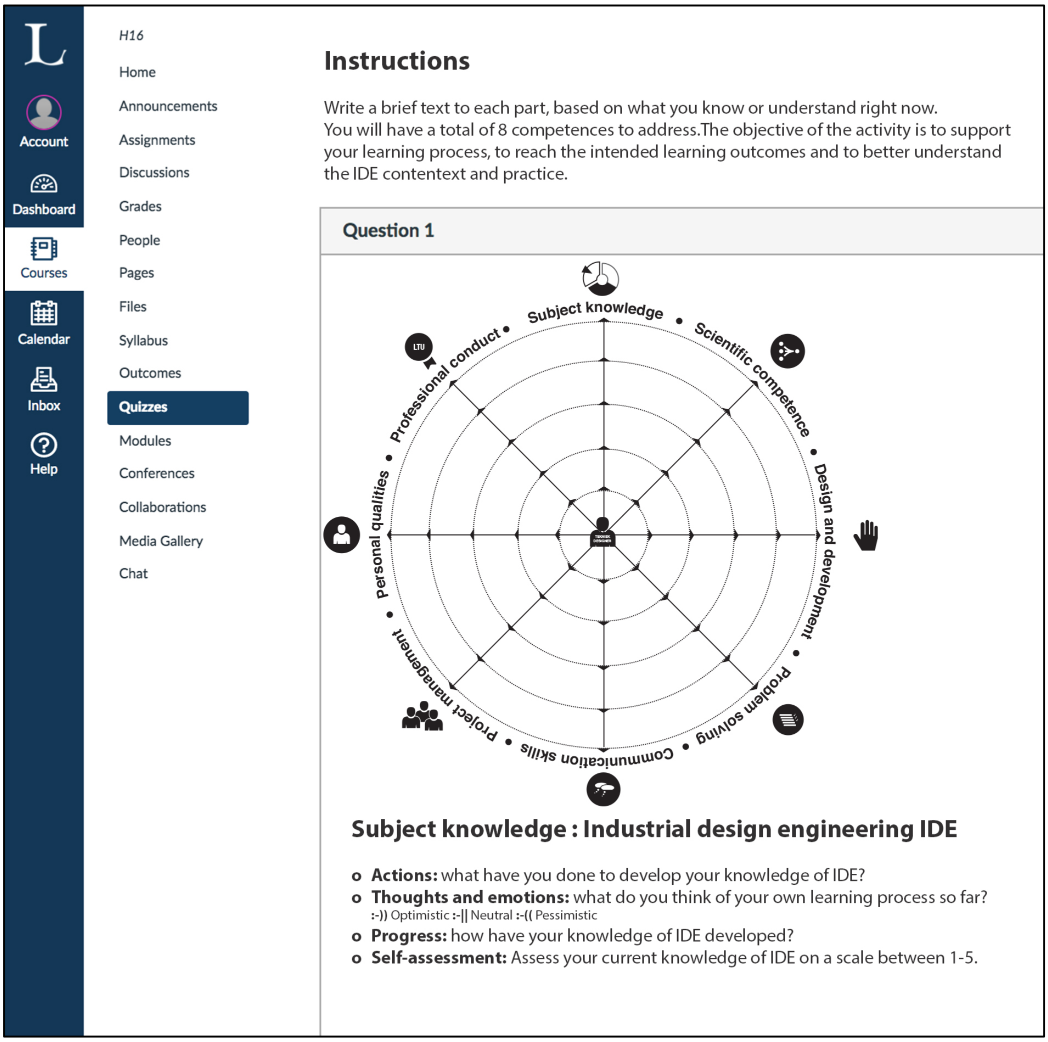

Figure 1. Illustrate the learning artefact 'competence profile' in use in a self-assessment activity during the course.

IMPLEMENT

The course design for the 2016 autumn semester included a number of learning activities, some implicitly, and other more explicitly linked to the learning artefact. Table 1 outline the activities that were directly linked to the artefact.

Table 1. Outline of the activities in which the learning artefact was used.

Course introduction	The course introduction included a learning activity in which competences for an IDE engineer were discussed, and the students reflected on which competencies that can be central in the role of an industrial design engineer. The concepts were then discussed, and teachers and students agreed on descriptions in the form of 8 competencies. The students thereafter valued their own perceived current competence in the different sections.
Self-evaluation	On five occasions during the course, each after a specific learning activity in which the students had a conceive-design-implement-operate learning experience, the students performed self-evaluation of their individual progression of the 8 competencies, see figure 1. The students were asked to describe: ▪ **Actions**: a description of what the student have done to develop the competence ▪ **Thoughts and emotions**: a description of how the student experienced the learning activity ▪ **Progress:** a description of how the student regard his/her own progression of the competence ▪ **Self-assessment**: on a scale of 1-5, how the student value him or herself for each of the 8 competences
Course end	The end of the course included a meta-reflection of the competences the students experienced they had developed, as a result of learning activities, actions and interactions, feedback and self-assessment.

OPERATE

The overall idea of the learning artefact ‘competence profile’ is that it shall be implemented in various ways through-out the IDE program, and that both students and teachers understand how learning activities can contribute to a progression of the competencies, in a continuous process of conceiving, designing, implementing and operating in program courses. This is however not the case today, as more work needs to be done about the learning artefact itself, and of how it should be implemented and operated in the IDE program.

OUTCOMES

The empirical data from the current learning experiment were gathered from multiple sources in the form of reviews of the submitted student self-evaluations, observations of how the artefacts were implemented and used during learning activities, and interviews with students and teachers. An analysis of the students’ submitted self-evaluations during the course illustrated that the artefact contributed to greater self-awareness and more deliberate actions taken. The students' understanding of their own competencies and how they progressed in the different teaching and learning activities evolved during the course. The course teachers also noticed that students spontaneously discussed the competencies and reflected on what they needed to do more or less of, in order to progress. This can also be seen in the students' self-evaluations throughout the course, which fluctuated from being cautious in the beginning, to becoming more optimistic of own capabilities during and towards the end of the course. In this case, the learning artefact contributed to the students' understanding on what they were intended to learn, what they actually learned, and what they did not quite master yet, and how they planned to act before the upcoming assignments. An interesting aspect in several of the self-evaluations is that the students describe what *they* need to develop, not what the teacher should "give" them, or what they will "receive" in upcoming learning activities and/or courses. This indicates self-awareness and might be a first step towards a self-regulated learning strategy. The course participants were first-year students. This is significant in terms of the artefacts' contribution in transforming mind-sets: from completing a course or an assignment, to acknowledging what is required in their future professional practice. The artefact hence seems to have contributed to a meta-reflection of what is required in the IDE professional practice and in the learning process as is illustrated in the following citation:

"To skip the moments you experience as boring, tedious or challenging, would make it difficult to develop and learn something new. It would in a larger context mean that you become very narrow in your professional capacity and the tasks you can undertake, or for that matter, are offered. I think that struggling through even tough tasks, not only will allow me to come out on the other side as a more knowledgeable and multifaceted industrial design engineer, but also as a happier and stronger person. "
(Student – self-evaluation HT2016 authors' translation)

An intent of the current learning experiment was that the artefact would support a focus on intents of teaching and learning activities, informed actions and students' understanding of what they actually had learned. The learning artefact provided greater understanding of what is required of a professional ID engineer. The learning activities provided experience of some of these requirements, and thus a better understanding of what the competences actually are about. This can be seen in the following citations from a student self-evaluation, regarding the competence problem solving:

"Solving problems have been recurring throughout the course, and the most important part of the final project. Because of my previous experience of technical education my skills in problem solving was more or less developed, but it was only a theoretical understanding. Now, my problem solving skills has been put into practical use, and I think this is the skill that I have developed the most, at the same time as I experience it as the most important part of a technical education."
(Student – reflection HT2016 authors' translation)

The use of the artefact varied between the different learning activities. All of the participants contributed in the introductory discussion of competences, and the role of an ID engineer, and the following self-assessment activity, and about 9/10 participated in the final reflection on the learning experiences. About 2/3 of the participants took advantage of the five non-graded self-evaluation reflections during the course. The course teachers for this reason recognise that the learning activities need to be developed in up-coming courses, since some of the students saw it as an extra assignment that did not give them anything in return. According to the teachers, the learning activities with the artefact contributed to a change of mind-set, by supporting students in explorations and experimentations, rather than completing single course assignments. They consider the learning artefact relevant in the on-going CDIO implementation.

DISCUSSION

The overall objective of this paper is to contribute with knowledge of how learning artefacts can support both students, in taking more informed actions in becoming a professional engineer, and teachers, in design of relevant teaching and learning activities.
Based on the current learning experiment we acknowledge the learning artefact's implementation to have contributed to a focus on the role and competence of a professional ID engineer. Furthermore, artefact's role in influencing the educational culture is rarely discussed. With this study we hence made one contribution to the development of knowledge about the role and use of learning artefacts to support the transformation of a strategic intent, i.e. implementation of CDIO standards, to some steps of change in the IDE teaching and learning practice. To fully understand the role and relevance an artefact can have in influencing an educational culture, and the teaching and learning experiences, more studies, and implementation in various learning activities are needed. One option could be to develop a 'learning framework' for students' competence advancement, in the form of e.g. a portfolio system. An important aspect is to integrate both students and teachers in the implementation, and that they see some kind of return on investment as a result of changing their teaching and learning practice. We consider the participants in the current study to have changed mindsets about both teaching and learning activities. The learning artefact contributed in encouraging a learning space, and served as a boundary object for discussing, and constantly returning to, the question of why we should do the things that we do in the IDE program. Students construct understanding of what is needed for a professional engineering role based on both explicit and implicit information, and a relatively small strategic change that contributes to their understanding of that role can improve their performance. The learning artefact promoted teachers and students' interactions, and gave both students and teachers support for independent informed actions. A starting point in this work was the challenge of transforming intentions and objectives into daily teaching and learning activities. If we can support leaders, teachers and students in better understanding the intentions of CDIO and the professional role through learning artefacts, then we can say that we have transformed the educational culture.

CONCLUSION

In summary, the learning artefact 'competence profile' and the previously described teaching and learning activities in which it has been implemented, we propose contributes to:

- Addressing CDIO *standard 1*, by clarifying and developing understanding of the IDE context of conceiving, designing, implementing, and operating products, processes and systems, among both teachers and students. Understanding of context and goals enhances the possibility for more students to adopt a self-regulated learning strategy.
- Addressing CDIO *standard 2*, by articulating essential IDE skills, and continuously discussing how these competences can progress through the synergy of integrating skills and subject knowledge
- Addressing CDIO *standard 3*, by creating a 'boundary object' that supports teachers in integrating and constructively aligning different skills and subject knowledge towards the main purpose of engineering education.
- Addressing CDIO *standard 4*, by providing teachers and students with a structured framework for engineering practice and through that supporting the progression of learning experiences into operative competences.

ACKNOWLEDGEMENT

We would like to express our deep gratitude to teachers and students in the introduction course to Industrial design engineering LTU, 1st semester of 2016, for patiently discussing, developing, implementing, thinking, contributing, and reflecting on the relevance of the artefact in the IDE teaching and learning practice.

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BIOGRAPHICAL INFORMATION

Åsa Wikberg Nilsson, Ph.D. is Director of Study in Industrial Design Engineering at the Division of Innovation and Design, Luleå University of Technology (LTU). She is one of the CDIO implementation managers at LTU, and responsible for educational reform within the IDE program. Her main research interests are design methods, collaboration, and design didactics.

Oskar Gedda, Ph. D. in pedagogy. His doctoral thesis focuses on educational culture in higher education. He currently leads the educational development unit at Luleå University of Technology

Corresponding author

Dr. Åsa Wikberg Nilsson
Luleå University of Technology
Department of Business Administration,
Technology and Social Sciences
SE-971 87 Luleå, Sweden
+46 (0)920 49 13 42
Asa.Wikberg-Nilsson@ltu.se