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RESULTS FROM CROSS-FERTILIZATION OF COURSES FOR IMPROVED STUDENT LEARNING

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ABSTRACT
This paper describes results from the development of two new industrial design courses in order to improve student learning in both practical and theoretical skills. Practical skills, such as model making and sketching, cannot be studied only as theory. These skills need training, implementation, and time to allow the knowledge to mature. The new course design build upon the CDIO framework where especially two standards are incorporated in the new course design: Standard 3 - Integrated curriculum, where personal and interpersonal skills, and product, process, and system building skills are interwoven with disciplinary knowledge, and Standard 5 - Design-Implement Experiences, where emphasis is on learning by doing, that the students will learn from actually designing something. This paper contains results from studies made during the first implementation of the two new courses, both from a teacher- and a student perspective. Redesigning several courses at the same time facilitates constructive alignment on course level where course activities are aligned with examination, and on *program* level where course content build upon previous courses and the proper learning outcomes are addressed at the proper time in the education *program*. On a *course* level, the results indicate that students are positive towards the interwoven practical and theoretical parts. Also, the student understanding of how different knowledge interact, both practical hands-on and theoretical knowledge, seem to have increased compared to previous years. On a *program* level, there are indications that much effort should go into organizing the sometimes new roles for the teachers and if overlooked could affect the course negatively, but we now have the knowledge how to implement the CDIO framework to develop courses for improved student learning.

Keywords: CDIO development, merging courses, theory-based courses, practice-based courses, teaching teams, Student learning, industrial design engineering.

1 INTRODUCTION

LTU has a tradition of emphasizing education development. For example, a pedagogical idea describing core values for all educations at LTU was developed and presented 2012 [1, 2]. Since 2013 the CDIO framework has been implemented at four programs, including IDE, at LTU [3]. Within IDE several sub projects within the CDIO implementation have been carried out [4, 5]. This paper describes the work of developing two new courses, based on four previous courses, at the IDE program as well as evaluating the outcome from the first round of these new courses. In order to aid the evaluation of the new course designs teachers and students are interviewed, as well as consulting course evaluations and student reflections in order to get a clearer view on the courses and whether the understanding and learning really are improved by the new course design.

2 CDIO

CDIO (Conceive, Design, Implement, Operate) [6] is an international collaboration and framework for developing or designing educational engineering programs. CDIO represents both a method and a continuous development for education programs and builds on teaching theories and outcome-based assessment [7]. Within CDIO there are twelve standards that refer to different areas of the educational content that describe a stepwise development process for continuous development. Each standard has a six-level criteria matrix (0-5) where the progress of the students can be assessed regarding how far

they have reached according to the CDIO standards. These criteria can be used to evaluate how well the course design contributes to the students' learning. The two main goals with developing the new courses at LTU were to achieve better *constructive alignment* [8] between tasks and the intended learning outcomes, (ILO), according to CDIO standard 3 [9] and also between sequential courses and to enable more *design-implement experiences* according to CDIO standard 5 [10]. Constructive Alignment, (CA), is described by Biggs [11] as *"a principle in curriculum theory that assessment tasks should be aligned to what is intended to be learned.", "In constructive alignment, the intended learning outcomes are written to include an activity, not just a topic."* Also one can use this approach to create an alignment at a higher level by aligning courses or whole programs in a more intentional and deliberate way. By applying *outcomes-based education* [12], where CA is one example, one can design a program where courses connect and where you keep a clear common thread throughout the program [11].

3 IMPLEMENTATION OF CURRICCULUM AND LEARNING ACTIVITIES

As described by Håkansson and Holmqvist [5], the four initial courses that can benefit from cross-fertilization and improve student learning were the theoretically oriented *Design Methods* and *Design Theory*, and the more practically oriented *Sketching* and *Modelmaking*. By combining *Design Methods* with *Sketching* into *Design: Process and Method* year 1 and *Design Theory* with *Modelmaking* into *Design: Theory and Practice* year 2 the aim is to improve student learning by implementing the CDIO framework, foremost standards 3 and 5, and increase the understanding for both the theoretical and practical content of the courses by interweaving practical course elements for explaining theoretical issues and vice versa (Figure 1).

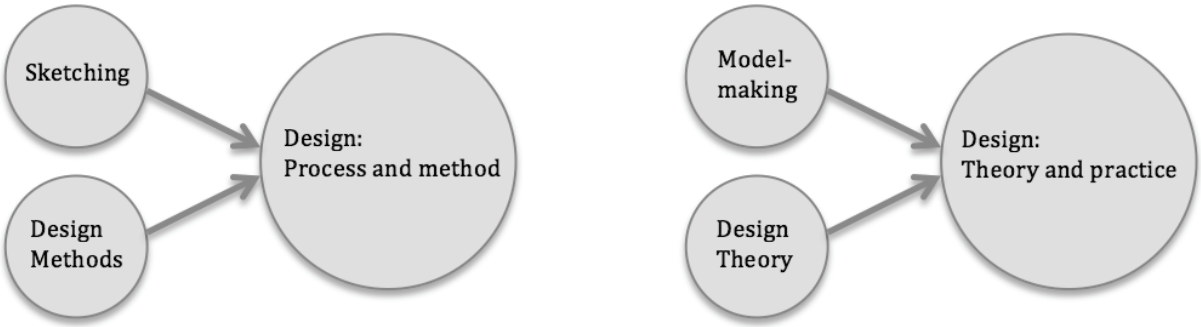

Figure 1. Course development

In line with CDIO standard 3 the new courses integrate disciplinary knowledge with practical skills-development and include several design-build experiences, implemented in small-scaled projects, for students to practice both personal and interpersonal skills. Where the previous curriculum offered a clear distinction between theoretical and practice-based content, the redesigned curricula integrate these to progress students' design-build learning experience in line with CDIO standard 5 [13]. The first year course now integrates theories of design methods and project management, with sketching and prototyping learning experiences. For example, design concepts are developed from sketches, to cardboard mock-ups to functional products made in wood with the help of various methods for design and creativity. The second year course now integrates design theories such as product semantics, aesthetics, usability, and user experience with practice-based skills as prototyping and modelmaking. For example, semantic aspects such as how to grip and handle of a product is directly explored with the help of foam mock-ups. By working hands-on and actually implementing a project, both personal and interpersonal skills are developed Aspects regarding both product or service functions are developed simultaneously as project management and teamwork aspects in order to develop the knowledge needed in working life. Also, the underlying theory is supposed to become more tangible and easier to understand and vice versa, by studying theory, the reason for why certain tasks are carried out the way they are, is supposed to become more substantiated and confirmed.

4 RESULTS

The results are compiled from voluntary course evaluations, teacher and student interviews, and observations of the students' learning processes by the teachers, and the students' own description and self-assessment of their learning process.

4.1 Teacher and student interviews and reflections

According to a teacher, which has been teaching sketching at IDE for 14 years, there is a slight but important improvement when it comes to the students understanding of *why* sketching is a powerful tool in the design process. At the same time, the teacher notices an indication of that the level of sketching skills and techniques has decreased among the students. Thus, the knowledge of *how* appears to been set behind, while the understanding of *why* has been reinforced. Compared to the earlier sketching course, the new course offers less, but more extensive sketching exercises which is negative for skill acquisition since there are fewer opportunities for learning activities. However, at the same times the new course appears to have positive effects of the students understanding on *why* as the assignments in the new course appears in a context that shows their relevance in a design process. A problem in the former sketching course was that the assignments had no connection to a project and was not always put in a clear context in the design process.

Student quote: "*I feel that I need more time to practice sketching. /.../ I have no aim to become a champion in sketching but it would clearly be useful to be able to sketch an idea pretty quickly.* "

What the sketching teacher wishes for in the future is more "qualitative" sketching classes where more focus is placed on emerging into the skill acquirement and direct personal feedback. Also, since sketching is a skill, more time on rehearsal and iteration needs to be conducted. Similar occurrence has also been noticed by the teachers in the course "Design: theory and practice" where the students build prototypes or models as a part of their project. The teachers says that the craftsmanship of the models are of lower quality now compared to the former course *Modelmaking* but that that the students are using their models in a more effective way and as a integrated part of the design process. The models are now used as a means to suggest or test new design solutions that solve broader design problems. For example, models are used in the process of designing gym equipment that encourages a wider group of people to work out at the gym. This is opposed to the former course design where the goal was to practice craftsmanship in modelmaking without solving any real-life design problem. Other teacher comments bring up that the students learning processes are better addressed and will probably lead to better prepared and more knowledgeable students later in the program. However, the new course design puts great effort for the teachers into the planning of the courses when well known previous course content cannot be re-used and new tasks and assignments need to be designed.

4.2 Self-assessment of CDIO standards

A self-evaluation of CDIO standard 3 shows that we have developed and implemented an integrated curriculum concerning personal, interpersonal, product, process, and system building skills development, thus ending up on level 3 on a scale of 5. For standard 5, the design-implement skills development starts day one in the program and lays the ground for good progression of skills throughout the rest of the program. There is also documented evidence of students having achieved the intended learning outcomes of the courses, thus ending up on level 4 out of 5.

4.3 Course evaluation surveys

Course evaluations have been conducted at the end of both of the new courses. The surveys are based on both quantitative assessments and freeform questions. For the first year course, Design: Process and method, the questions regarding "*What was good about the course? Please give examples."* display a wide variety of topics, but the project assignment was mentioned several times, and the students showed approval of the new course design with practical classes and workshops as exemplified in the following quotes:

"*The project assignment made us get very good understanding of the work process for design.*"

"*The project-based learning approach vas very helpful in connecting all industrial design engineering competences.*"

The response to the freeform question "*If you were to teach the course next time, what improvements would you make?"* was almost entirely related to planning issues (course structure, time planning, assignments, communication between teachers) that can be exemplified with the following quote:

"*I would send out information in time, which is not in the last minute, that won't help the students at all. The forward planning has been bad throughout the course. Lectures have been poorly planned and with a large portion of wasted time between the lectures. The teachers have given different information depending on who you ask*"

For the second year course, Design: Theory and practice, the freeform questions were mainly positive towards mixing theoretical and practical work, especially the practical parts and workshops were perceived in a positive manner. For the question "*What was good about the course? Please give examples."* This can be summarized in the following quotes:
"*The combination of theory and practice has been good. Fun to mix lectures and workshops.*"
"*The laborative work has been good and very rewarding.*"
For the question "*If you were to teach the course next time, what improvements would you make?"* the main aspects were related to improvement of planning, structure, and course goals, as well as modelmaking connected to an open ended project work. This can be summarized in the following quotes:
"*I would work with a better and more structured planning, as well as more precisely specified assignments.*"
"*Narrow the project in order to have greater chance that the design solutions are suitable to build physical models from."*
The quantitative evaluations of the courses show a decline in how the courses are perceived by the students for an excerpt of questions on a 6-grade scale as shown in Figure 2. The course impression of the first year course have decreased from a mean of 4.6 for the previous courses the latest two years to 3.1 and the second year course have decreased from 4.5 to 4.0. The main objection from the students is lack of planning and organization from the teaching team when conducting the courses. This requires a serious work through to improve this aspect for coming courses.

	Design: Process and methods 2016	**Design metods 2015**	**Design metods 2014**	**Sketching 2015**	**Sketching 2014**
Response rate	27.4%	30.43%	98.41%	35.29%	56.45%
Overall course impression	3.1	4.1	3.8	5.3	5.2
Satisfied with my efforts	4.7	4.8	4.9	4.5	4.7
Theoretical teaching and learning activities	3.5	4.2	3.9	5.6	4.8
Practical/creative teaching and learning	4.6	5.2	4.8	5.3	5.0
	Design: Theory and practice 2016	**Design theory 2015 2015**	**Design theory 2014 2014**	**Model making Quarter 4 2015**	**Model making Quarter 3 2015**
Response rate	79.7%	28.57%	87.84%	46.67%	67.39%
Overall course impression	4.0	3.4	4.2	4.9	5.6
Satisfied with my efforts	4.8	4.7	4.7	5.3	5.1
Theoretical teaching and learning activities	4.6	4.0	4.0	3.9	5.3
Practical/creative teaching and learning	5.2	4.0	4.3	4.9	5.8

Figure 2. Quantitative course assessments

4.4 Student description and self-assessment of learning process

In both courses, the students had mandatory assignments to reflect upon their learning process and conduct a self-evaluation of their level of competence related to a competence profile that is under development [4]. The competence profile includes eight essential skills for IDE-students: Subject knowledge, Scientific competence Design and development, Problem solving, Communication skills, Project management, Personal qualities, and Professional conduct. The students' reflections on their own learning process are mainly positive towards the course designs and describe that they have gained knowledge in both disciplinary knowledge as well as personal and interpersonal skills, as well as the rest of the IDE competences. However, some students perceive some lack of practical training. The students' view of learning in the courses can be exemplified in the following quotes:
"*I went from knowing concepts of aesthetics and design but not quite having a deeper understanding what they mean, to really understand how important it is to have these concepts in mind when designing a product. What has been an important part of the course is that I understand these theoretical concepts better now that we have made use of them in various model making exercises*."
"*The parts of the course where I have made the most progress the most are when we have had the opportunity to do things practically.*"
"*The course and, not least, the course project has been very giving and I think I've grown a lot. The course was very different in comparison to other courses I've taken, which made it exciting. The openness in the course meant that we had the ability to take own initiatives and it was really just myself who put a stop to the level that each assignment could reach.*"

"*There are two parts that I think I understood less than others: modelmaking and working with Photoshop. I understand less in these two tasks because we have not had enough of practice.*"
"*Sketching has been very educative although there have been few occasions with sketching.*"

5 DISCUSSION AND CONCLUSIONS

This paper describes an ongoing process of course and program development where the two courses in focus have so far only been conducted once.

5.1 Course level implications

The quantitative part of the course evaluations shows a decline in the students' perception of the overall quality of the courses. Especially the previous practice based courses in sketching and model making have gotten higher overall assessments than the new redesigned courses. However, these course evaluations don't measure student learning or progression of skills. Rather they display a measure of how 'fun' the student perceived the course to be. High course evaluation scores means that the students are satisfied with the course, but not necessary that they actually learnt anything. By having the students reflect upon their own learning in mandatory assignments we know have some evidence that they actually learn. In the previous courses we could only review students' final results, but not the reasoning behind why the result turned out the way it did. The main source of criticism of the course design by students has been that the courses have seemed rather unstructured and information has come to the students late. However, now that these courses have been conducted once, the major part of the planning and structuring have already been done and much of the effort prior to the next round of courses can be focused on planning learning activities well ahead as well as bringing the teaching team to a shared understanding of the course content.

5.2 Program level implications

The results indicate that cross-fertilization of courses are beneficial for the students learning processes but we need to continuously develop the courses, foremost the general planning of the courses and the information flow. The redesign of these courses has, however, put much larger effort on the involved teachers to plan and sync learning activities in order to achieve a good progression of learning throughout the program. The impact of these changes is believed to be more salient in a couple of years when students have completed their education. Hopefully, this development will result in a more conscious use of sketching, model making and prototyping, as well as their theoretical underpinnings and greater knowledge of why, how, and when the students should use sketching and model making. These skills will hopefully be more naturally used as tools in the design process throughout the IDE-program as opposed to isolated skills that have been learnt but not always used by previous students.
The process of transforming into using teaching teams instead of individual teachers in courses will also be expanded to include other courses in the IDE-program. The next natural step in the process of integrating the program curriculum is to also merge courses in industrial design with courses in natural sciences, mathematics, and mechanical engineering to further interweave the students' skills.
As this is also somewhat a 'learning-by-doing' process, we now have the knowledge that the general course cross-fertilization works, and can focus on developing the learning activities. The CDIO-framework is a good starting point when developing or redesigning education and has proven to be highly useful to structure the redesign of the courses by providing important aspects to consider in engineering education. By this process of redesigning these courses the people involved have also gained greater understanding of the rest of the IDE-program as there is now a larger focus on using previously learnt skills in later parts of the education. The program will hopefully have fewer overlaps of both subject knowledge and personal and interpersonal skills now that more effort is put into progression of the students' skills and knowledge. One aspect to consider in further development is that when teaching of practical skills is incorporated as parts of courses, there is a risk that they will be perceived as lesser part of the course and will drown in other learning activities. The amount of teaching time for these practical skills have also declined as compared to earlier, meaning that the student will have to take greater responsibility in actually using and practicing these skills continuously to progress in their learning.

6 CONCLUSION

It can be concluded that the merging of practical and theoretical skills in our two new courses have generate both positive and negative outcomes for student learning. It appears that the students in both of the courses use their practical skills (sketches and model making) in a more intelligent way. The problem, however, is that model making and sketching, as a tools for design thinking, appears to be held back since the students lack the skill required to express and depict meaningful material. The evaluation of the course outcomes shows that there is still work to be done to improve synchronization both within each course and between the different courses. There are also promising results in many areas, especially the student understanding on why, how and when to use different practical tools in the design process. To monitor how the change will affect results over time, more evaluations will be conducted later in the education.

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