CEP - CDIO ENABLING PLATFORM AS A CATALYST FOR COURSE INTEGRATION

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ABSTRACT

This contribution presents and discusses a CDIO enabling platform (CEP) used within courses at the Department of Management and Engineering, Linköping University, Sweden. The platform consists of a physical setup manifesting several potential real R&D situations, including production aspects. When present in courses, it is combined with the scenario technique based on a potential business case. The physical hardware of this teaching platform is a modular multi-utility bicycle, commonly referred to as a cargo-bike, together with assembly and welding fixtures.

From a learning theory perspective, lack of course integration and curriculum progression is problematic. For instance, the rationale of constructivism tells us that new knowledge is largely based on and created from previous knowledge. It follows that courses must "talk" with each other in the sense that students are able to use newly acquired knowledge from one course directly in another.

CDIO implementation is yet another aspect where issues of insufficient course integration and progression adds to the problem. CDIO is basically about bridging the gap between theory and practice. And since heavily theory oriented traditional courses are hard to align with the CDIO syllabus, an implementation process may benefit from solutions that foster course integration.

CEP enables and facilitates the implementation of the CDIO standard in several ways. Furthermore, from the curriculum perspective, the platform may serve as a catalyst for course integration. This paper discusses and exemplifies both these issues, CDIO implementation and course integration, using an intermediate computer aided engineering course during the third semester of the program, where the learning outcomes also includes innovative thinking and oral presentation techniques.

KEYWORDS

Integrative learning, Course Integration, CDIO Enabling, Hardware, Experiential learning, Scenario technique, Standards: 3, 4, 5, 6, 7, 8

INTRODUCTION

A program syllabus often addresses the CDIO framework by looking at the whole program which results in theory-heavy "C"-courses during the first years of the program, and large project courses at the end. However, the heavy theoretical start-off is usually pointed out as the main driver for drop-outs. To deal with this, one often finds one or a few practically oriented courses during the first year of the program, also known as cap-stone courses, aimed at placing the students in the correct engineering context, meeting their expectations of their chosen profession and so forth. Nevertheless, the surrounding courses often remain with their traditional theoretical didactic approach, thus missing making connections with existing applications, etc.

Furthermore, for a long time, and in particular after the advent of the IT era, there has been an increasing demand for integrative abilities among members of society as a whole, but perhaps especially when it comes to those who are set to develop new products and services. When we examine how the traditional training of the new developers (i.e. students on technical programs), one could raise concern over the lack of utilization of integrative possibilities. After all, studying at a technical institution is definitely a multi-disciplinary experience, aimed at a multi-disciplinary profession. Most engineers, even specialists, are expected to continuously process and act on information from different disciplines.

From a student perspective, the absence of multi-disciplinary challenges is perhaps less obvious if the courses are given in series, but even more if given in parallel (which is often the case). Curricula that offer courses like isolated sources of knowledge hardly resemble what awaits after graduation, and from the experience of the author of this paper, this is something most students are aware of. This is where integration between courses becomes an issue.

The lack of utilization of integrative opportunities, among others, is a driver for change in higher engineering education curricula. Not only regarding the purpose of multi-disciplinary training of the students, but there are also other potential benefits of a more integrated learning environment, as will be discussed in this paper. This contribution will also present and discuss a proposal for a new curricula model. At the center of the model is a physical platform that serves multiple (integrative) purposes.

FRAME OF REFERENCE

Previous research

The founding idea for the learning platform presented and discussed in this contribution originates from previous research at Linköping University concerning so-called Low-cost Demonstrators (Hallberg, 2013). They are meant to serve as a cost-efficient cross-disciplinary resource during a product development process, without any intention of reaching product-like maturity. Figure 1 illustrates the fundamental role of such a demonstrator.

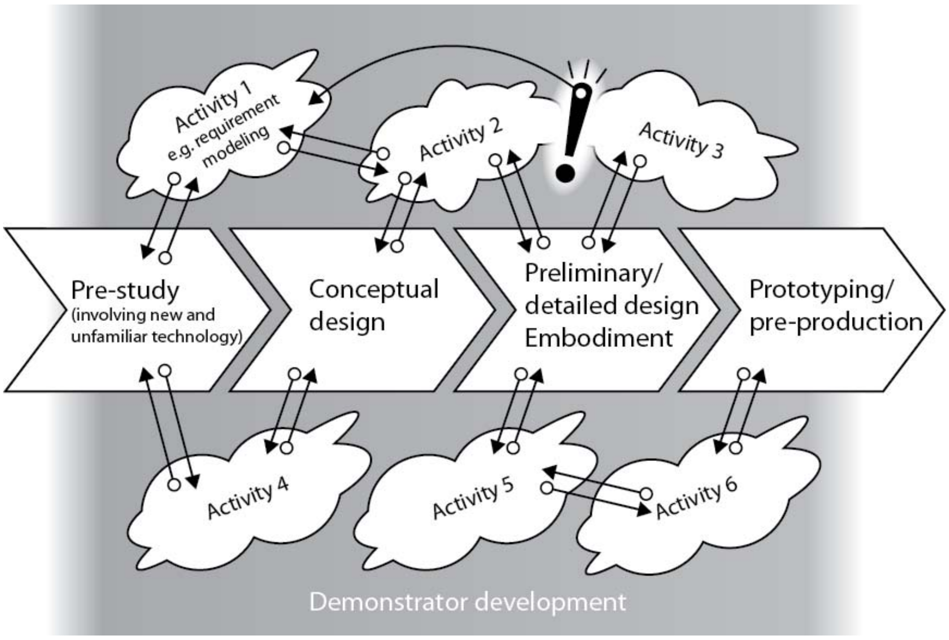

Figure 1 A product development process supported by a parallel demonstrator development process (the grey background)

Furthermore, and connected to applying physical manifestations during courses, previous research on a freshman course on the Mechanical Engineering program at Linköping university shows the possibilities of using a low-cost approach when letting the students design and build a simple catapult as part of a basic CAD course. However, by building the catapult the students are forced to apply their knowledge of, for instance, calculus, mechanics, and physics (Hallberg, 2012).

Learning Theory

If we look at CEP as a (physical) platform for creating and exchanging knowledge, utilized by students and members of a faculty, it is necessary to apply different aspects of learning theory when discussing the role and functioning of the platform.

Experiential learning

The theories of Kolb (1984) are fundamental when discussing learning, or creation of knowledge, by interacting with the surrounding environment, which obviously is the case when working with physical learning platforms. Kolb defines learning as the process whereby knowledge is created through the transformation of experience, also known as experiential learning. This model is composed of four elements: concrete experience, observation of and reflection on that experience, formation of abstract concepts based upon the reflection, and finally testing of these new concepts. The process then starts over with the concrete experience that follows from observations of the testing. Kolb calls this the learning cycle, which can be seen in Figure 2. This spiral of learning can begin with any one of the four elements, but typically begins with a concrete experience.

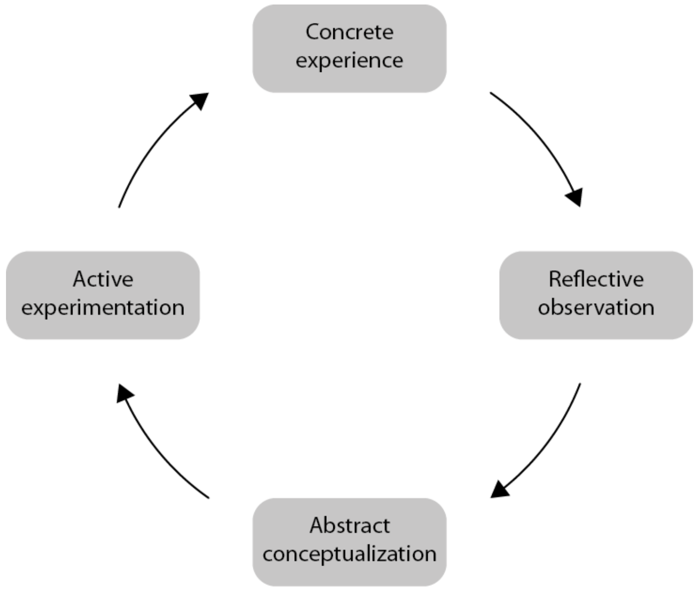

Figure 2 Kolb's learning cycle.

Moreover, with the theory of experiential learning and its further evolvement, Kolb has made conclusions about what he refers to as "learning spaces" (Kolb et al., 2005). The concept of learning spaces is a framework for understanding the interface between students' learning styles and the institutional learning environment. Furthermore, and relevant to this contribution, Kolb stresses the importance of promoting learning in higher education through institutional development.

Integrative Learning

The concept of Integrative Learning is basically about connecting different disciplines throughout the curricula – also referred to as interdisciplinary education. Several references relevant for this contribution can be pointed out. As one of the early recognizers of integrative learning, Huber and Hutchings (2004) state that [… Fostering students' abilities to integrate learning—across courses, over time, and between campus and community life—is one of the most important goals and challenges of higher education. The undergraduate experience can be a fragmented landscape of general education courses, preparation for the major, cocurricular activities, and "the real world" beyond the campus. But an emphasis on integrative learning can help undergraduates put the pieces together and develop habits of mind that prepare them to make informed judgments in the conduct of personal, professional, and civic life. …]

From an analysis of integrated programs, Froyd and Ohland (2005) conclude that [... The most significant long-term outcome of integrated programs may be faculty development. Significant collaboration among faculty is required to implement a successful integrated program and may lead to the development of faculty learning communities through which faculty grow in their understanding of learning and teaching…] and that […Design projects have the potential to help students make connections among subjects, material, and applications. The process orientation of design holds promise for improving the systems thinking of engineering students.] Finally, Froyd and Ohland state that [… The implementation of integrated curricula has helped expand the use of cooperative learning and student teams, especially in design projects. The use of these pedagogical approaches and the clustering of students in multiple classes have aided the formation of learning communities. Learning communities have likely played a role in improved retention and improved learning outcomes…]

Recent conclusions about engineering students’ perception of their chosen profession have been drawn by Singer et al. (2015). Singer finds [… sufficient evidence to indicate that the integrative learning module is useful in integrating the humanities, social sciences, and engineering, and helping further develop students’ perceptions of engineers. …] and continues to conclude that [… With subjects often taught in isolation /…/ students often fail to understand the true applications of math and science concepts, which may limit their ability to choose engineering as a career. …]

Furthermore, Singer states that [… students using contextualized, integrative, and interdisciplinary approaches may be able to develop better higher order thinking skills to solve complex engineering problems While one course alone may not be able to solve limitations in the entire curriculum, it facilitates a transition toward integrative, interdisciplinary, and wholistic thinking, making it easier for students to accept other similar courses, and with time develop the skills to integrate ideas, processes, and knowledge between different courses, and continue developing these skills throughout their careers. …]

Regarding curricula integration and its effect on avoiding drop-outs, Walden and Foor (2008) observe that [… student experiences with departments and faculty where students were not effectively integrated into the formal and informal environment and did not connect with curricular content contrast with student perceptions of a department and faculty who offered the promise of inclusion in a supportive environment with student perceived relevant curriculum. …]

Problem Based Learning

Edström and Kolmos (2014) conduct a structured comparison between the CDIO framework and the model of problem/project based learning, concluding that [… The fundamental idea of CDIO is the integrated curriculum, where discipline-led and problem/project-led learning are meaningfully combined. For existing programmes, it is often necessary to increase the share of PBL activities. But that is not sufficient; a curriculum is not integrated just because it contains both problem/project-led and discipline-led courses. The synergy comes from integrated learning experiences, where students simultaneously acquire disciplinary knowledge and professional engineering skills. ..]

THE CDIO ENABLING PLATFORM

This section will describe CEP - a CDIO enabling platform, first conceptually and then by reporting on the current status of the platform at Linköping University.

In academia, it is common for of engineering design program curricula to be outlined such that courses that cover different disciplines are given in parallel. Stakeholders of this project are represented on the board of studies representing the Mechanical Engineering bachelor program at Linköping University. Each 30 ETCS credit semester on this program is divided into equal periods stretching over roughly 8 weeks of studies. Furthermore, each period contains two 6-credit courses given in parallel at full speed and another 6-credit course stretched out over the whole semester and thus given at half speed. See Figure 3 for an example.

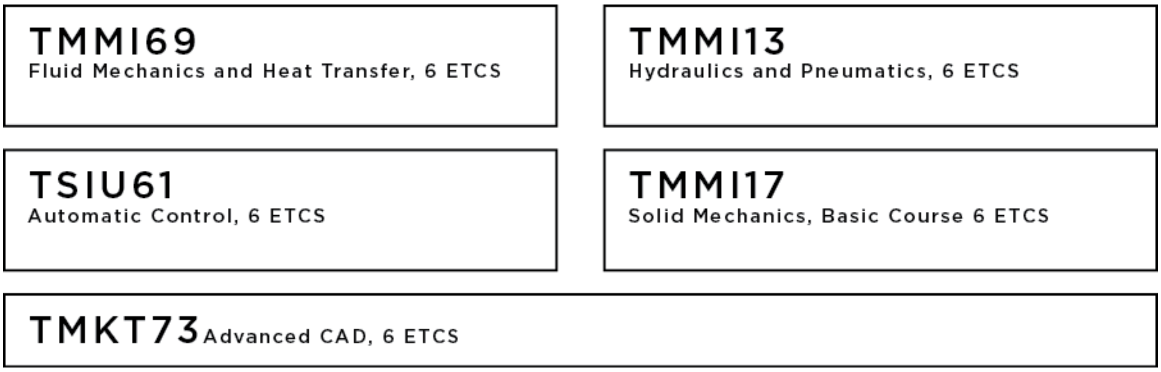

Figure 3 Outline of the 3rd semester of the Mechanical Engineering bachelor program at Linköping University

These stretched-out courses are traditionally identified as typical CDIO courses. This is probably due to the greater allocated time frame, which in turn makes it easier to implement a Design-Implement-Operate phase during the second half of the semester. The full-speed courses, on the other hand, tend to be dominated by a conceive phase with minor traditional laboratory exercises at the end of the course.

As regards the third semester of the mechanical engineering bachelor program, this is exactly the case. See Figure 5. The question now is whether the “DIO-part” of the stretched-out course can “serve” the surrounding “C-heavy” courses with a clearer Design-Implement-Operate phase, enabling them to reach a similar CDIO-implementation level to the stretched-out course. What are the obstacles and what would the benefits be?

The concept of CDIO enabling

The stretched-out TMKT73 is basically an intermediate CAD course with a typical CDIO arrangement where students spend almost the whole first period conceiving advanced approaches to CAD-modeling, e.g. top-down functionality, skeletons, programming, automation tools, analyzing, and PLM. The second half is organized around a fictitious product development project where the students form engineering teams that are set to win a sub-contract, supplying the development and manufacturing of a novel utility bicycle with modular capabilities, see Figure 4. These kinds of vehicles are referred to as cargo bikes. In order to provide the project scenario with sufficient realism, a rear module of such a cargo bike was prepared in advanced, consisting of both a detailed CAD-model and a physical counterpart, complete with standard components and manufacturing fixtures for welding and assembly. The concept of involving physical representations and enabling hands-on experiences in CAD-courses is based on previous experience of successful results regarding learning achievements (Hallberg, 2012).

With the Design-Implement-Operate phase of TMKT73, the reason for building a project scenario around a cargo bike has been well thought-through. A vehicle like this is able to stage, but yet simplify, a number of mechanical engineering challenges. Bicycles are fundamentally simple and familiar products, largely consisting of standardized components and thus suitable for learning situations with inexperienced students. However, with the advent of e-bike technology and large automotive supplier companies like Bosch and Yamaha entering the market it is very convenient to make reference to and build an industry-like case.

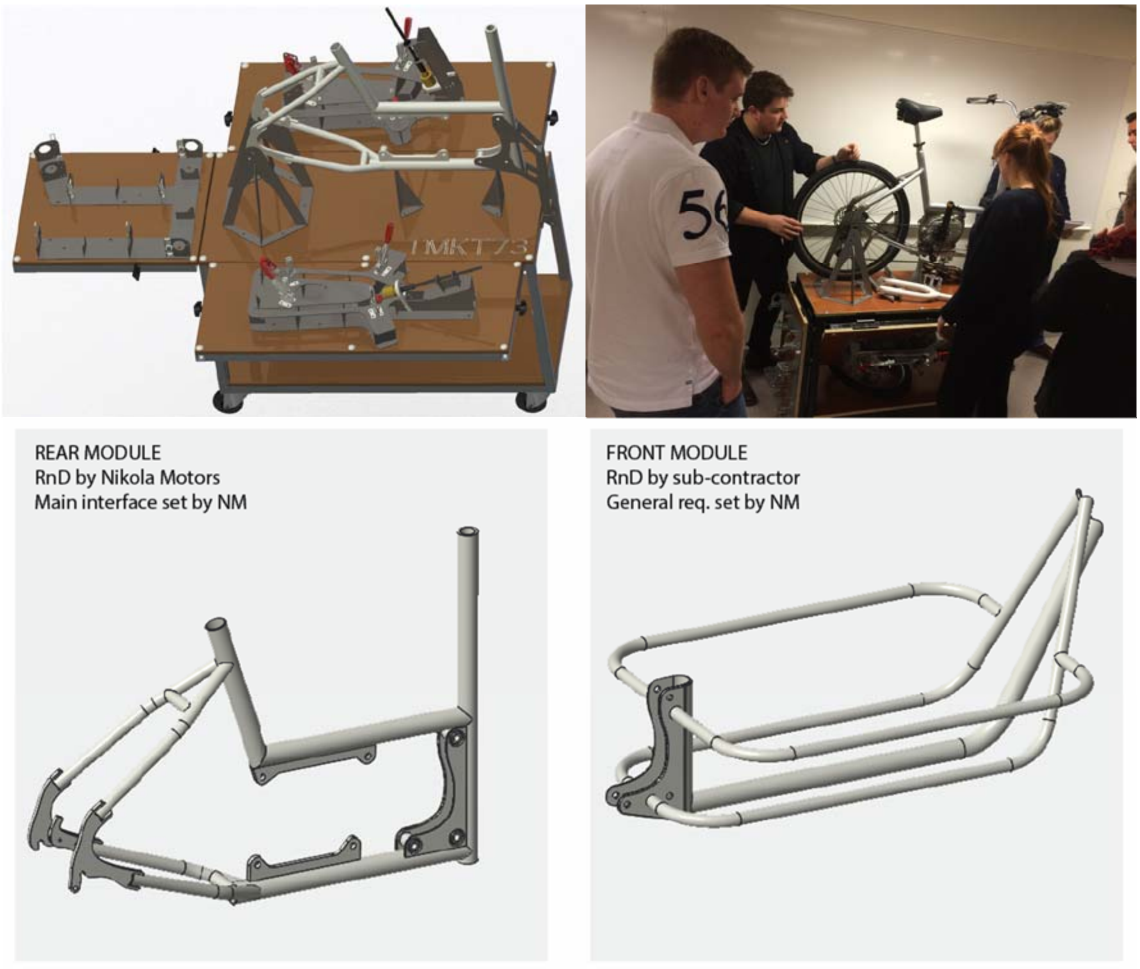

Figure 4 The complete CAD-model of the current CEP (top left), its physical counterpart in a classroom situation (top right), and explanatory pictures from the project description of TMKT73 (bottom)

However, the TMKT73 is surrounded by four other courses during the semester, representing four separate disciplines. They are during the first period fluid mechanics and heat transfer (TMMI69) and automatic control (TSIU61), and during the second period of the semester hydraulics and pneumatics (TMMI13) and solid mechanics (TMMI17). Taking a holistic view of these disciplines and at the same time considering the cargo bike project assignment in TMKT73, one realizes that they could all be relevant for any vehicle development project.

After examining the existing need for active learning (i.e. laboratory exercises) within the surrounding courses, the examiner of TMKT73 (and also author of this paper) has launched a study to investigate how the four disciplines can be represented or integrated into the cargo bike project. We are therefore looking for what we call integrative interfaces between the Design-Implement-Operate phase of TMKT73 and the active learning components of the other courses. See Figure 5.

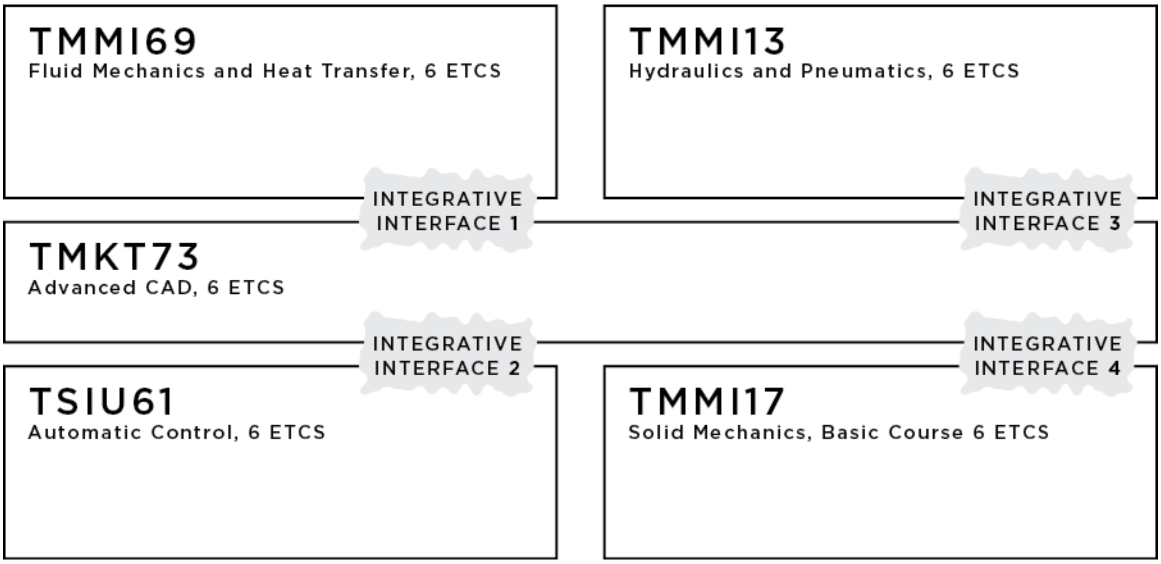

Figure 5 Outline of the 3rd semester of the Mechanical Engineering bachelor program at Linköping University

When considering the presence of both the digital and the physical model of the cargo bike intended for the project scenario in TMKT73, it is natural to search for the integrative interfaces there. By doing so it is also natural to introduce the term *platform*, which is justified both literally and metaphorically.

- Metaphorically speaking, we picture the platform in a wider meaning, more like an organizational unit that different stakeholders on a particular semester gather around to create and process knowledge while executing the curriculum. Examiners and program planners could use the platform as a base to build and organize courses upon.
- Literally speaking, referring to the actual presence of the physical artefacts that resembles the platform, i.e. the assembly station with welding fixtures seen in Figure 4. For instance, the station is equipped with wheels and may thus easily be moved around between different classrooms, workshops, labs, etc. Also, the fact that the chosen product (the cargo bike) is modular opens up for developing different (front-) modules serving different purposes in parallel courses without ruining the overall scenario.

Current status

It is crucial that the platform is manifested in a way that allows for interaction with the surrounding courses. A foundation for the current platform has been under development since mid-2015. It consists of a modular cargo bike including assembly and welding fixtures together with a highly flexible and parametrized CAD-model residing in a PLM system.

However, only the rear module of the cargo bike has been fully realized with the purpose of serving the project scenario in TMKT73 during the fall semester of 2015. This was a first test of the concept of a CDIO-enabling platform and is currently undergoing evaluation. During the fall semester of 2016, the idea is to incorporate one or more of the surrounding courses to actively make use of the platform.

To achieve this, a project was initiated during the spring of 2016 to develop and realize one or more front modules of the CDIO-enabling platform. The modules would include integrative interfaces that allow the other courses to interact with and co-exist on the same platform. Such interfaces could, for instance, be arrangements for enabling drive-by-wire or self-balancing capabilities (TSIU61 Automatic Control), well thought-through structures that can provide material for laboratory exercises (TMMI17 Solid Mechanics), innovative hydraulic or pneumatic arrangements, e.g. active damping systems (TMMI13 Hydraulics and Pneumatics).

The search for integrative interfaces was conducted within their final year project by students on the very same program that the platform is intended for, i.e. the mechanical engineering bachelor program. Thus, project team members were themselves students some eighteen months prior to the development of the interfaces. Results were based on both interviews (of the examiners concerned) and regular concept generation by the design team. Another requirement was that the implemented integrative interfaces should be motivated by at least three CDIO standards. Preliminary outcomes from this project are shown in Figure 6.

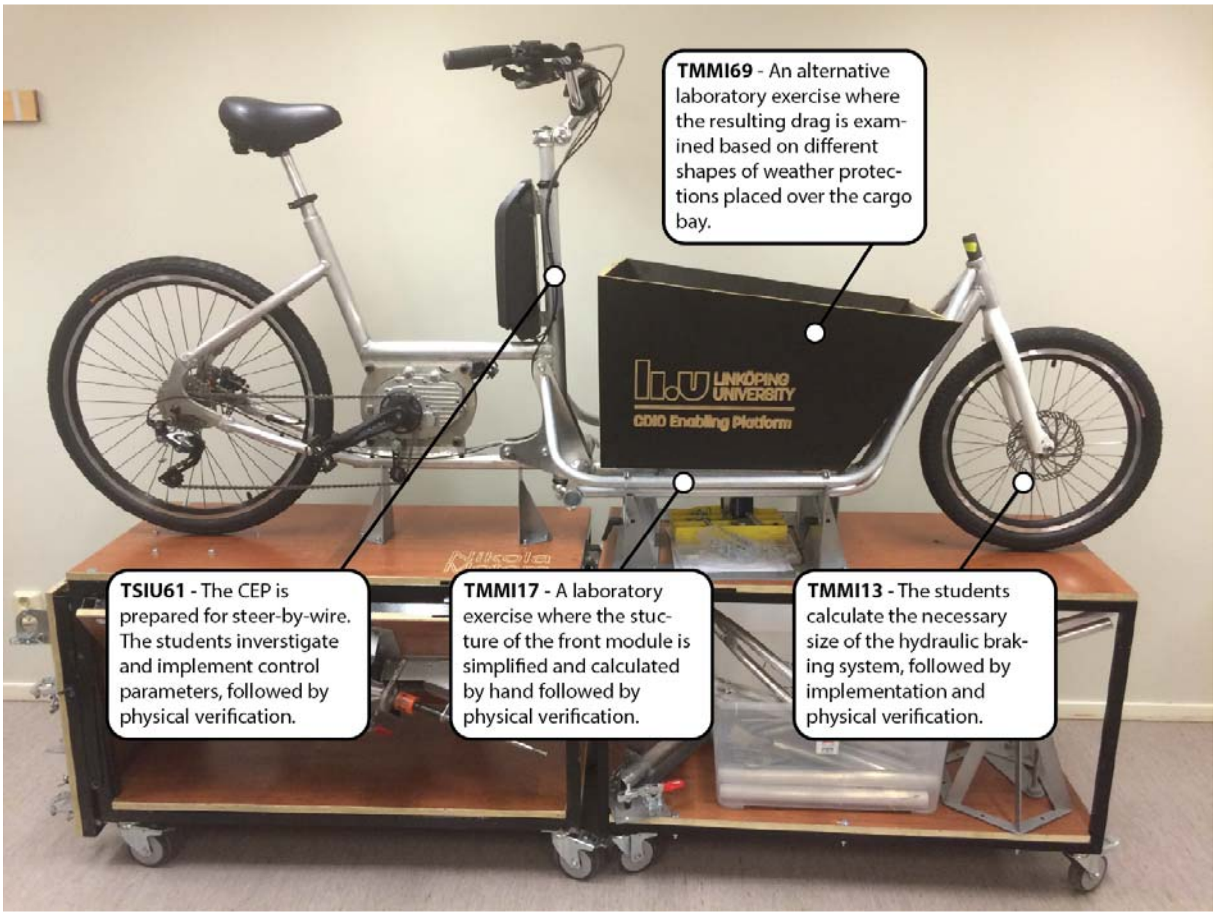

Figure 6 The CDIO Enabling Platform rear and front module coupeld together. The call-outs show tentative integrative interfaces on the platform.

DISCUSSION

The CEP described in this paper could rightly be questioned depending on how institutions choose to implement the CDIO syllabus on their programs. It is true that when a program as a whole is treated as the subject of implementation, the implementation process consequently allows for conceive/theory-heavy courses during the first years of the program, compensated by applied and practically oriented project courses during the final years. To some extent this is unavoidable and this is also typically the way technical programs are organized today. However, there are a number of drawbacks to this kind of CDIO implementation. One of the more obvious is that theoretically oriented courses tend to be a driver for drop-outs (Walden and Foor, 2008). One of the underlying reasons is that such courses lack a clear connection with the profession the program is supposed to aim for and that the student has based his or her decision upon. The CEP proposed here could therefore also be considered for implementation on programs that have already gone through a CDIO implementation process.

But there are also other issues that can be addressed using the proposed platform. Based on experience from the work on the board of studies representing the Mechanical Engineering bachelor program, issues that call for improvement can be identified:

- General inconsistency and incompatibility regarding the level of CDIO-implementation among the courses on the Mechanical Engineering bachelor program.

- General lack of communication between examiners of courses that are given in parallel.

- Among the examiners there is a general lack of awareness of their courses' position in the curriculum. This may in turn result in insufficient understanding on the part of the examiner regarding the student perspective, e.g. in terms of workload, etc.

The board of studies monitors the execution of the curriculum continuously. Well aware of the issues stated above, the board is constantly looking for ways of improvement. One way of addressing several of the issues above is to have all the examiners “semester-wise” gathered around the proposed CDIO-enabling platform. This would mean that the stretched-out course on each semester (TMKT73 in the case above) would act as the host of the physical platform and of the Design-Implement-Operate activities of all the courses on that particular semester. The expected outcomes from this approach (that would have to be measured and verified later) would be that the five examiners would have to communicate and synchronize their individual “DIO”-activities. Merely by doing so, one could expect understanding from the examiners regarding the student perspective on one hand and the other examiners’ situation on the other.

As we move forward discussing the proposed CEP, let’s take the viewpoints of the imagined stakeholders who to some extent are expected to benefit from the platform, and at the same time, where applicable, point out the potentially activated CDIO standards. The concept as a whole naturally addresses *CDIO Standard 3 – Integrated Curriculum* and indirectly *CDIO Standard 4 – Introduction to Engineering*.

Students

The students on an engineering program are the recipients of information taught by the institution. Notably, they are in transition from inexperienced high school graduates to being employable in the eyes of the industry. They should expect that every effort from the institution is aimed at preparing them for their life after graduation and their chosen profession. From this standpoint, the platform may play the following roles

- The platform places the learning activity, whatever it might be, in a context more similar to the industry. Especially combined with a scenario. This clearly addresses *CDIO Standard 6 – Engineering Workspaces*.
- The platform may serve as a catalyst for discussion about the role of the engineer (*CDIO Standard 6 – Engineering Workspaces*).
- Depending on the applied scenario, the platform enables and requires multi-disciplinary problem-solving which addresses *CDIO Standard 7 – Integrated Learning Experiences*.
- The actual presence of physical hardware may also foster implementation of *CDIO Standard 8 – Active Learning*. In the case of the above exemplified cargo bike, its modular properties make it especially suitable for designing and interaction with (simplified) subsystems (modules) of the whole system. If students are allowed to design such a subsystem, we can also address the *CDIO Standard 5 – Design Implement Experience*.

Individual examiners

After all, many examiners active on mechanical engineering programs are either trained product developers or at least have a view of where their discipline fits into the product development domain. However, many examiners are nevertheless comfortable as theorists or are forced to act as such while performing their duties. In these cases, the introduction of a physical platform/scenario based tool for learning could help and encourage examiners and teachers who would like to transform their teaching.

From this perspective, the CEP could facilitate implementation of the CDIO framework as a whole, but it also specifically points towards *CDIO Standard 9 - Enhancement of Faculty Competence*. For example, if the examiners are involved in the process of defining a platform, they will consequently have to apply their domain of expertise onto the platform and at the same time adapt to the other examiners and their domains.

Board of studies and program organizers

The people responsible for planning and organization of the program may use the CEP concept of CDIO enabling through a physical platform, such as the one presented in this paper, with the purpose of facilitating and ensuring CDIO implementation. Furthermore, the importance of promoting learning in higher education through institutional development is stressed by Kolb and others (Kolb et al., 2005). One can argue that CEP has the potential to play a vital role in such a development process.

Researchers

Naturally, the CEP could be utilized by researchers within the institution and thus facilitate the connection between research and undergraduate education. This would mean that researches take part in the planning and formation of the platform.

Industry

As mentioned earlier, one of the purposes of the CEP is to enable a more industry-like learning environment when executing a curriculum. However, the proposed concept could very well be introduced to industry partners in order for them to take part in the formation of a platform. One scenario could be that a representative of a company identifies a specific demand in terms evaluation of a concept. The platform and a connected scenario could then be arranged to allow the company to conduct evaluation studies while the students are working on the platform (where the concept is represented).

FUTURE WORK

Implementation of the proposed CDIO platform will continue and results will be evaluated during the fall semester of 2016. A survey study is being planned in order to measure the impact of the platform on the learning outcomes from the courses concerned.

Further development of the platform itself is also expected. Discussions are also going on about involving companies who could make use of the platform. Potentially, a company could "plant" a platform during a semester, providing the necessary hardware along with a scenario that would contain requirements or specific assignments that the company would benefit from.

A further question to be answered is if there are other semesters on the Mechanical Engineering bachelor program where the same approach could perhaps be applied, but not necessarily using the same platform.

Other discussions involve whether the platform could be used across multiple cohorts or even across different programs. For instance, one such suggestion is to let Industrial Engineering students practice project management within the current product development scenario in TMKT73.

CONCLUSION

Enabling integrative learning is one of the keys to making the learning environment relevant in the eyes of the students. Implementation of the CDIO framework is partly justified by the same principal – making the trained student relevant for the industry. Thus, what we see is a symmetry in relevancy. By enabling and fostering a multi-disciplinary learning environment throughout the curriculum of the engineering program, the students become better prepared for a future first employment.

A CDIO-enabling platform, as proposed in this paper, could serve as a general tool for program planners to ensure a multi-disciplinary learning environment. The platform consists of a modular cargo bike and assembly station that is used within a product development scenario.

The purpose of the platform is to enable and facilitate integration between parallel courses during the same semester in order to create a multi-disciplinary learning environment.

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BIOGRAPHICAL INFORMATION

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