

ADAPTATION OF THE CDIO-FRAMEWORK IN MANAGEMENT COURSES FOR ENGINEERING STUDENTS - A MICRO-LEVEL APPROACH

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ABSTRACT

The CDIO-Framework is developed in order to enable engineering students to engineer (Crawley et al 2014) and is relatively straightforward when applied on courses and projects that have a high degree of practical, hands-on engineering elements, such as e.g. developing software or a physical product/prototype. However, in many engineering programs a large part of the courses concern managerial aspects such as project management, leadership, marketing, innovation and entrepreneurship, especially in later years of a program. We are well aware of the fact that the CDIO-framework is developed to work on program-level, however, applied on management courses, commonly only the Conceive and Design can be obtained. Furthermore, these courses are not always structured in such a way that they immediately builds on each other. This dilemma has caused us to adapt CDIO to circumstances of the courses that we give and to reflect upon how more of the CDIO spirit can be transferred to our own modules and activities on course level. The aim of this paper is therefore to develop ways for application on a micro-level where the CDIO spirit can be implemented in management courses at engineering programs. In the paper we give three different practical cases where the CDIO-framework have been applied. The cases show that CDIO works both on micro-level, e.g. in two hour exercises and within the frame of individual courses. For management courses, and especially courses in entrepreneurship and marketing, the framework need to apply a more extrovert focus, i.e. on verification of customer needs and benefits, rather than on technological solutions.

KEYWORDS

Micro-level CDIO, CDIO in management courses, extrovert approach on CDIO projects, Standard 8: Active Learning

INTRODUCTION

The CDIO-Framework is developed in order to enable engineering students to engineer (Crawley et al 2014). According to the CDIO-website (www.cdio.org), the CDIO-framework “is based on a commonly shared premise that engineering graduates should be able to: Conceive – Design – Implement – Operate”. Conceive implies that the students should be able to achieve a comprehensive view over - and an understanding of - the context. This includes i.e. the underlying needs or problems from which the CDIO-project is to be planned. The design part is about forming and creating a solution that fulfills the needs, or solves the problems, identified in the previous phase. After this the implementation phase occur, and at this stage the activities is about test and verification - i.e. to make sure that the solution works. In the final phase - operate - the students “go live” with their solution. Following this chain of activities makes CDIO a very hands-on approach to learning while solving relevant problems. Furthermore, and according to Crawley et al (2014) active learning is an important part of the CDIO-framework. The students need to engage and take responsibility for their own learning, as well as for the learning of their colleagues. The use of mixed methods for learning is recommended as way to facilitate the level of activity, engagement and learning among the students (Norrman, et. al 2014).

The CDIO-framework has gained ground in engineering education all over the world and it is closely related to the thoughts of Biggs (2003). Biggs divide between declarative, i.e. theoretical knowledge and procedural (practical). When combined they generate conditional knowledge, i.e. knowledge of what theory that solves what problem and how this is done. The final step in the pyramid of Biggs is Functional knowledge, where a person is experienced and masters an area. The CDIO-chain, as framework for learning, is relatively straightforward when applied on courses and projects that have a high degree of practical, hands-on engineering elements, such as e.g. developing software or a physical product or prototype. However, in many engineering programs a large part of the courses deal with managerial aspects such as project management, leadership, marketing, innovation and entrepreneurship, especially in later years of a program. We are aware of the fact that the CDIO-framework is developed mainly for application on a program-level, however, applied on management courses, commonly only the phases “Conceive” and “Design” can be obtained within the frame of single courses. Furthermore, these courses are not always structured in such a way that they immediately build on each other, which in turn implies that the whole CDIO-chain cannot be obtained regarding these management oriented subjects even on a program level. This dilemma has caused us to adapt CDIO to circumstances of the courses that we give and to reflect upon how more of the CDIO spirit can be transferred into modules on a micro-level, e.g. exercises and activities that are not immediately connected to engineering per se.

Another phenomenon that we have noticed regarding the CDIO-chain is that it, to high degree, is compatible with the traditional product development chain, which according to authors such as Blank & Dorf (2012) works well in established firms where customer needs are identified and known, but works less well for innovative startups that not yet have verified that their ideas corresponds to the need of their customers. If the CDIO syllabus is regarded, this might be a shortcoming if entrepreneurship and innovation is aspired for, as is also noted in the second version of the CDIO Syllabus (Crawley et al 2011).

If it is important that our engineering students also should be able to innovate, or at least engineer in innovative contexts, verifications and tests needs to be expanded to cover also marketing aspects. Lean product or concept development could be used for this purpose, e.g. Minimal Viable Product approaches (cf. Eric Ries, 2011) that strive towards launching what e.g. Philip Kotler and Theodore Levitt referred to as “the core product” in their layer-based product models (Frankelius et al, 2015). An MVP-approach requires agility, iteration in fast loops in order to verify that the customer needs are as close to real as possible.

The aim of this paper is therefore to develop ways for application of the CDIO approach on a micro-level where the CDIO spirit can be implemented also in management courses at engineering programs.

Below we present three types of cases from our own teaching experience: one 2 hour exercise case, one real-life project case and one case concerning pedagogic experiment about including reality encounter. After each case description the case is connected to the CDIO framework.

CASE 1: “THE COLORING BOOK FACTORY”, A 2-HOUR CDIO-EXERCISE

“The coloring book factory” is an experience-based exercise where students learn about how different forms of work tasks can require different forms of organization, i.e. organic organization versus mechanistic organization. This exercise is a part of an organization management course given to first-year engineering students. For the purpose of this exercise the students are divided into groups of about 6-8 individuals. One observer (i.e. a person that does not participate actively in the exercise but observes and writes down what happens in the group) is also assigned per group. The exercise is done in two stages - the design stage and the mass-production stage (lasting 20 minutes each). To complete the exercise each group is given 8 crayons in 8 different colors and four bunches containing 20 preprinted A4 - front pages with an uncolored picture of a castle and the text “Coloring book”. The observers are informed of their task and they are given a form for their observations. The students receive written instructions in the beginning of the exercise, telling about the two steps, the time frames and the prerequisites and rules of the game.

When the first part is finished the students are sent on coffee break and the observers together with the teachers select the winning design. At this moment it commonly becomes obvious that some groups have staked for quality by means of looks and others for efficient production. The selected design commonly represents the best compromise between an attractive and a mass-production-friendly design.

In the second stage each group receives a copy of the winning design and they are given 5 minutes to plan the mass-production phase. At this stage they are allowed to buy extra production equipment (i.e. more crayons). As the mass-production starts they realize that the time frame is short. That implies that they need a leader and that they need to trim the production line. Commonly they also realize that they need quality control functions.

After the exercise is finished calculations of economy are done based on a price list received by the groups at the beginning of the exercise. Points are awarded per completed front-page

and points are deducted for extra crayons (if the group has decided to buy any). The winner is the company that have earned the most. When the winner is designated the observers share their observations and the students discuss, both within the smaller groups and in class what happened during the exercise.

The coloring book factory exercise from a CDIO-perspective

This micro-level exercise gives us an opportunity to apply all steps of the CDIO framework to a single course activity. Both the product - the book cover - and the organization of the group develop during the exercise following the CDIO pattern.

For example the first two steps, Conceive and Design, can be seen as happening when students are given opportunity to analyze the instructions and rules of the game and from that plan their work and create strategies. This happens both before the design stage and before the mass-production stage. During these both stages both Implementation of plans and strategies, as well as Operation where the strategies are tested and re-developed, are taking place. In parallel, Conceive and Design are also happening when the uncolored page is developed into a design proposal during the design stage. Here the students have to make strategic choices between quality aspects and aspects important for efficient mass production.

When both stages are completed, students' learning is enhanced through discussions facilitated by the observers and the teachers. The teachers also highlight relevant organization theory that helps to explain what happened and what worked well during the exercise. Having the possibility to go through all four steps of Conceive-Design-Implement-Operate in one session creates a memorable learning experience that despite its seemingly simple tasks delivers vital insights into the pitfalls and success factors of organizing for creativity and for mass-production respectively.

CASE 2: PROJECT MANAGEMENT AND REAL-LIFE THESIS PROJECTS - A CDIO-INTEGRATED APPROACH

During their third year of studies our engineering students write theses for a Bachelor's degree. In one of the engineering programs this is done in collaboration with firms located throughout the region meaning that the students work with real-life challenges that actual firms struggle with and get to visit their firm multiple times during the semester. The first part of the thesis writing consists of an initial project done in groups of 6-8 students where an overview of the firm and its challenges is created. During the second part the students work in pairs and write a scientific report based on a selected real-life challenge that the firm needs support with.

Our case involves the first part - the initial project - and deals with successful integration of learning about project management into the process of thesis writing itself. The project stretches over 15 weeks and begins with the student group receiving a mission statement that has been developed by the firm together with course teachers. Received mission statements range from vague to very broad to more specific - depending on factors such as developmental stage of the firm itself, its size and complexity, etc.

During the project the groups' main tasks include deciding and motivating a realistic scope for the project, planning and giving time estimates for project activities (e.g. collecting data), presenting their progress to a steering committee consisting of the course teachers, following up activities and fulfillment of goals, as well as providing the firm with proposals for further action. The projects are run as professional projects with one of the group members being assigned the role of project manager, a pre-study and a project plan, tollgate meetings with the steering committee, logging of work hours dedicated to the project, and a project report. This process is supported through a few traditional lectures on project management, as well as a textbook, but the most important learning experiences happen when the students work hands-on with project management tools applied to their actual real-life projects.

Throughout the project there are four tollgate meetings at set dates. For these meetings specific deliverables are prepared and presented by the project groups (e.g. the project plan on the second meeting). Before each tollgate meeting there is a "test presentation" session where students do a trial run of their presentations intended for the steering committee in front of each other as well as a teacher in communication. After these test presentations the students receive feedback on both their power point and the oral presentation and have the possibility to adjust these before meeting the steering committee on the following day.

The project ends with a conference where firms' representatives as well as all involved teachers participate. Every group presents their results both in a short written report, on a poster and orally. Firms' representatives get the opportunity to ask questions and learn more about the other participating firms and their project results. After the conference the groups write a report summarizing how they applied the project management tools and what they have learned.

Integrated project management course from a CDIO-perspective

As academic teachers we work within strict time constraints and we constantly try to convey more and more material in a limited amount of time. The type of course described here gives us an opportunity to include a lot of different types of learning in one course. The approach with integrated project management and real-life projects contributes greatly to the development of personal and professional skills and attributes highlighted in the CDIO Syllabus (Crawley et al 2011), e.g. task prioritization, making decisions in face of uncertainty, professional courtesy, as well as trust and loyalty. Furthermore, this approach also focuses on development of interpersonal skills connected to teamwork and communication, e.g. team operation and growth, networking, oral presentation, and advocacy. Simultaneously, the projects entail learning about the external context and business context through working with real-life projects while also letting the students engage in a conceive-design-implement process.

Many of the above skills can otherwise be considered difficult to fit into a pressed schedule of an engineering program, yet this approach lets us develop these skills while working on a program-relevant project. The students find this course demanding and confusing at times, however they are always proud of the end result and their own growth in their professional role.

From the teachers' perspective the course is unpredictable since firms and real-life projects are involved. It is also a time-consuming process to find firms with interesting challenges that have the possibilities to engage with students on a project. Ultimately the course is very rewarding - for both students and teachers and we continue to develop this concept further with each edition of the course.

CASE 3: CDIO-INSPIRED MARKET RESEARCH COURSE

One philosophy at Linköping University is the ambition to stimulate both inter-disciplinary and trans-disciplinary knowledge. By inter-disciplinary knowledge we here refer to mixing of different scientific disciplines. In the educational context that means students can choose courses from a broad palette. It is notable that the Department of Management and Engineering include many disciplines at the same place, for example technology, entrepreneurship, business administration, economics, political science and juridical science.

By trans-disciplinary knowledge we refer to the ambition to mix academic and practical knowledge. In educational context this is expressed by giving students the opportunity to learn both academic and practical knowledge.

In combination inter-disciplinary and trans-disciplinary knowledge form something that we have called intra-disciplinary knowledge ("in" from inter and "tra" from trans). See figure 1.

		Knowledge workers	
Theoretical scope		University -based academics	Trans -disciplinary: Practitioners as well as university-based academics
	Inter -disciplinary: Two or more disciplines	Inter -disciplinary knowledge	Intra -disciplinary knowledge
	Single -disciplinary	Internal -disciplinary knowledge	Applied single disciplinary knowledge

Figure 1. Matrix model describing theoretical scope vs. kinds of knowledge workers.

One illustration of the mentioned knowledge philosophy (intra disciplinary knowledge) was our experiment conducted in 2016 in the business administration course Marketing and Consumer Behavior. The class consisted of about 50 students from countries such as France, Germany, Sweden, Australia, Spain, England, Peru, Taiwan, China and Switzerland.

In the experiment students had to investigate consumer behavior and motivational factors behind certain behavior. In CDIO language, the students should design a solution to the mysterious problem of understanding real-world consumer behavior in the farming business. We focused on products with probably high customer involvement because the product is important and expensive. We also focused on a certain sector in which products could be assumed to be important both for business use and pleasure, and we here connected to an on-going research project at Linköping University (the Grönovation project). The product category was farm tractors. The idea came from Christoffer Anderson, CEO at The Rural Economy and Agricultural Society in East Sweden region. He wanted a solution to the mysterious problem of farm tractor buyer's behavior. The student's team mission was to identify 5 persons that have bought a new farm tractor during the last year. The information on each person (case) should then be collected by means of visits, telephone conversation or mail correspondence (or combination of these methods). Questions to be analyzed were the following:

- Why did the tractor buyers choose to invest their money in a tractor instead of something else?
- Why did they choose the specific brand among tractors?
- Why choosing that size (= price level) of tractor?
- What is special with the tractor brand chosen (according to the customer)?
- What do they say about the value-price relation?
- How, in short, did the buying process occur?

Planning for this work can be seen as Conceive and Design in CDIO language. The students were asked to write a report on their findings. After the empirical result students should have an analysis section in which they related their main empirical findings to well-selected concepts and models found in the course literature. In the middle of the work period, each student team had the opportunity to present their work in progress to the rest of the class and get feedback on how to proceed in the best way. The conduct of the investigation, fieldwork, as well as writing of the report was inspired by the CDIO frame of reference.

The way we organized the final seminar could be of general interest because it was an example of Implementation and Operation in CDIO language. We co-operated with Vreta Kluster, an innovation platform outside Linköping. Students presented their findings to other students, the course director and not least practitioners. The practitioners from the farming industry became an "authentic test platform" for the ideas that the students had developed. Some of these practitioners worked with trading tractors, so the students got the opportunity to bring their results into operation. By operation (in CDIO language) this was not only student operation but also a potential for practitioners operation.

CONCLUDING DISCUSSION

The cases described above show how the CDIO-approach can be elaborated on so that it fits both single exercises, (e.g. the coloring book factory) and can be integrated within the frame of a thesis-writing course. The third case shows upon that the “operate” phase can benefit from benchmarking with actors outside the university. Our preliminary conclusion is that the CDIO approach can successfully be adapted to the micro-level, and this can bring a lot of benefits to engineering students.

The examples, upon which we have applied the CDIO-framework, is not typical engineering applications - rather it is examples coupled to management issues. This rise the question of whether CDIO could also be useful outside an immediate engineering context. We think so. To us the framework is almost as universal as the initially referred work of Biggs, i.e. the knowledge pyramid, in which theoretical and practical knowledge, through application and experience, can create the type of knowledge we want our engineers to have - i.e. that we want them to be able to engineer. If we assume that engineering abilities consist of more than construction, e.g. creativity, entrepreneurship and new ways of thinking and combining knowledge and skills, into new and innovative items, it is of great importance to apply the framework also on management related subjects. Just inventing is not enough to become an innovator, the latter requires diffusion, and diffusion requires management.

As teachers, we find the CDIO approach useful when planning both course modules and single activities. We would like to highlight that it can be challenging to go from traditional teaching and learning methods to a CDIO-based approach - both for students and teachers. Introduction of new types of learning requires communication and support throughout the process, especially when the students meet this concept for the first time. Nonetheless, the leaps in development that we observe in our students make it very rewarding and motivating for us to continue to use and develop the framework and its applications.

We also want to highlight that the CDIO can gain ground also in managerial courses e.g. those focusing on marketing and entrepreneurship. But in such courses especially the implementation phase will put more focus on verification of customer needs and benefits and on verification of the business model, than on the technology used or the technological solution. This means that in such courses CDIO needs a more extrovert focus. Such processes are also highly iterative, which means that the students need to use agile approaches.

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