CDIO FACULTY DEVELOPMENT COURSE – BUILT-IN IMPLEMENTATION

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ABSTRACT

To successfully implement the CDIO approach in engineering programs, a holistic approach is required, connecting the philosophy of the program with teaching and learning activities in the courses. One influential component in this interaction is faculty members and their competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning (CDIO Standard 10). As an effort to support such faculty development, a group of universities has been conducting activities directly aiming to enable and drive CDIO implementation in the participating universities (mainly within the EIT Raw Materials programme). In this paper, we will continue reporting and critically reflecting on these CDIO-based faculty development endeavours. Initially, a faculty development course was launched in 2016 at Chalmers University of Technology and offered to participants from other universities (Bhadani et al., 2017). The paper starts by outlining the adaptation of the course into its second version, followed by investigating the experiences from the first group in 2018. The course was designed to suit both experienced and novice faculty. It offered a staged introduction to CDIO implementation alternated with sessions in which participants worked on their own course development. The rationale for this design was to increase the direct usefulness for the participants, in that they should feel engaged and involved during learning and be able to immediately apply their learning to their own course. To estimate the impact of the course on participants' actual course design and implementation, participants' final presentations and feedback were analysed. Interviews were also conducted to gather information about the changes made in the participants' own teaching, as well as the perceived influence of the CDIO course on those changes. The paper could be used to support organizers of faculty development courses in other universities, by documenting a model that can be implemented as a standard faculty training course.

KEYWORDS

Faculty Development, Raw Materials, Course Development, Standards: 9, 10.

INTRODUCTION

Changes to a business organization are inevitable as they can be driven by many internal and external factors which can come in many forms, shapes, and sizes (Todnem By, 2005). Those inevitable changes are not only restricted to business organizations but also apply to academic organizations such as higher education universities, which aim to modernize engineering education. Considering the wide range of stakeholders involved in today's education system such as society, students, teachers, institutions, employers, governments, industries and so on, it is not sufficient that one person can act as a leader and bring changes, but rather a collaborative effort is needed (Walkington, 2002). Further, Walkington (2002) took inspiration from Fullan (1993) regarding the importance of every unit in a change process and proposed that both top-down (programme to course) and bottom-up approaches (course to programme) are needed to bring improvements towards education development.

Within the CDIO Initiative, the training of faculty members has been identified as one of the critical aspects of the effort to reform and enhance engineering education (Crawley et al., 2014). Malmqvist et al. (2015) conducted an extensive survey on forty-seven CDIO universities to evaluate outcomes and barriers for CDIO implementation. The survey results highlighted that the CDIO Standards 9 and 10, which focus on the enhancement of faculty competence, have shown modest improvements compared to the other ten standards which revealed substantial progress (Malmqvist et al., 2015). It seems that faculty development is a rather slow procedure, which requires continuous effort and sharing of knowledge and experience to build progress. Learning from experience is a useful and necessary approach, but it can be accelerated by also learning from the experiences of others.

Faculty development is addressed in many universities through courses related to teaching and learning, mentorship etc. One method for enhancing faculty competence is to introduce and apply CDIO in faculty development courses. This has been applied in the project *CDIO within EIT Raw Materials Knowledge and Innovation Community* (Edelbro et al., 2017). In 2016, a faculty development course was launched at Chalmers University of Technology introducing CDIO to faculty within the Raw Material sector (Bhadani et al., 2017). In 2018, a second version of the course took place, again at Chalmers, now under the umbrella of CDIO2 project which is a continuation of the previous efforts. Here, the focus shifted mainly to the implementation of the CDIO approach (Clausen et al., 2018).

This second version of the faculty development course incorporated previous participants' feedback, which highlighted the need to utilize the time during the CDIO course to make improvements to their own courses or programme (Bhadani et al., 2017). Another adjustment from the previous course was the documentation of the results from the course's outcomes. The second version of the course was organized in a workshop format to increase active involvement and produce direct usefulness of the course for the participants. The course was also designed to target both experienced and novice faculty members. The continuous improvement of this CDIO course is aimed to produce a standard course with appropriate guidelines for continuous education of faculty members. To develop and improve this course further, we posed our research questions:

1. Which CDIO components from the faculty development course are perceived as useful from faculty to develop their own course?
2. How do faculty make use of the information they receive during the course?

The research questions support the development of elements that can be implemented in a standard faculty development course. The paper is organized in the following sections: We begin by reviewing the literature on faculty development and proceed by describing our current course. Then the KJ method and semi-structured interviews are used to investigate

the results of the current course. The aim is to evaluate the critical aspects of the course and present guidelines for developing and conducting a standard CDIO course for future reference.

LITERATURE REVIEW

Högfeldt et al. (2013) interviewed programme leaders of eight different master programmes within engineering fields from Nordic countries and found that a substantial amount of negotiation and collaboration is needed to run a master programme. They also added that a collaborative effort of sharing ideas and experiences is needed both from programme leaders and faculty members to successfully run a programme (Högfeldt et al., 2013). An investigation by Malmqvist et al. (2008) regarding the development of faculty competence within three Nordic universities highlighted two typical categories of skills required for implementing change in academia: pedagogical competence and management competence. The pedagogical skills could typically help a faculty member understand what to change in a course or programme, and the management skills could assist them in implementing the changes. Both skills along with appropriate individual motivation and encouragement by the institution are needed to bring about change in various contexts in academia (Malmqvist et al., 2008).

Farmer (2004) reported that there is a need to measure the outcome of the faculty development courses on faculty themselves. This is related to following-up with the development work of the faculty as their expertise varies widely. Finding objective evidence with such development is often regarded as challenging (Farmer, 2004). Dolmans et al. (2002) reported a trend in faculty training for problem-based learning that content experts tend to use subject-matter for discussions while non-subject experts emphasized the process expertise for facilitating discussions. This distinction needs to be considered while evaluating the results of a faculty development course as results presented by the participants can be either process-oriented or content-oriented. To further longitudinal knowledge transfer, Loyer and Maureira (2014) proposed a mentoring approach for training new faculty to motivate the use of active learning and implementation of gradual changes in a course. This resulted in knowledge transfer between an experienced faculty member and a novice faculty member in a longitudinal framework, although the aspect of resource allocation was questioned (Loyer & Maureira, 2014). Chuchalin et al. (2015) also recommended follow-up with the faculty member development at specific intervals to discuss the successes and failures of their implementations. Their results also highlighted that in order to implement changes, a faculty member needs to be aware of their roles and responsibilities for the entire programme outcomes and this is especially challenging (Chuchalin et al., 2015).

From literature, it is noticed that the active engagement of faculty during the training activity is a critical step to get them started with the thinking process. Further, an active follow-up can support the implementation of new ideas and evaluate their development. This is also useful for understanding the learning process of a faculty member. The change process is related to the personal motivation of a faculty member, together with the new pedagogic and managerial skills. Further, it can be suggested that any formal training activity should at least show the role of a course in an engineering programme, and how the programme matters to stakeholders, so that the participants can appreciate that their contribution as educators is for a greater cause.

DEVELOPMENT OF THE CDIO FACULTY DEVELOPMENT COURSE

The development of the CDIO faculty course was itself based on the CDIO principles. We aimed to create a coherent course with elements of active learning where the implementation of the CDIO mind-set to participants' own courses was in focus. The targeted audience were course examiners, teachers and teaching assistants who wanted to rethink their course in a structured way with the assistance of CDIO experts and peers. The course was given at Chalmers in two days, and there were 15 participants both from raw materials universities and from universities active in the CDIO community.

Course Organization

The course was designed based on the principles of constructive alignment where learning and assessment activities map to the learning objectives of the course (Biggs, 2014). The intended learning objectives were based on the first version of the course (Bhadani et al., 2017) but were focused on a course level:

L1. Explain how the CDIO approach can be implemented in engineering education.
L2. Apply the CDIO Methodology to course development, including
   a. Formulating learning outcomes on the course level
   b. Developing appropriate learning activities for discipline-led learning and a problem-based/project organized learning
   c. Developing appropriate assessment methods aligned with the intended learning outcomes

Our target was to create a learning community of educators, here in the role of students, who would engage and interact with each other and develop their own courses (Zhao & Kuh, 2004). The structure consisted of pre-preparation activities, seminar sessions, case studies, and group work. The course activities are presented in Table 1 with their rationale. Each activity was conducted for one hour with breaks in-between.

A key aspect of the revision of the faculty development course is to increase the engagement of the participants and support the actual implementation of the presented material to their own courses. The course preparation and the submitted presentations helped the course instructors get an overview of the participants' background, issues, and expectations, and it also helped the participants reflect on and summarize what they want to improve in their course before attending. Case studies were used to inspire the participants and showcase examples of appropriate implementation of the CDIO approach. The multiple sessions provided the context and the information for the participants to work and discuss during the group work. The group sessions aimed to help the participants reflect on the information they received in the previous sessions and translate them to their own teaching. Sharing of experience with the other participants was a key in this activity. The participants also received individual feedback and comments from the instructors during the group sessions. The final presentation acted as an incentive for the participants to keep working in their course during the two days. Additionally, it was an opportunity to concretize the information they received and receive feedback from the instructors and the other participants.

EVALUATION OF THE CDIO FACULTY DEVELOPMENT COURSE

The overall assessment of the result of the CDIO faculty course was based on an analysis of the participants' final presentations, short interviews with three of the participants to receive feedback and instructors' own critical reflection. The analysis was conducted to evaluate the changes participant intended to include in their courses after attending this course. This can

potentially reflect on the research question about what component of the faculty development course was found to be useful and applicable to the participants' courses. The semi-structured interview was conducted to receive feedback for the participants' motivation, the course content, and organization as well as the utilization of the information they received.

Table 1: CDIO faculty development course organization and its content.

Activity	**Topic**	**Content and Rationale**
Course Pre-preparation	Participants' own preparation	To prepare 3-slide presentation including the learning objectives, learning activities and assessment techniques of their own course.
Day 1		
Session 1	Introduction and Participants Presentation	To help participants get to know each other and their expectations, especially since the audience was international and from different disciplines.
Case Study 1	Mechanical Engineering - Sustainable Development and Mathematics	To inspire the participants and showcase examples of appropriate implementation of the CDIO approach.
Session 2 (Parallel)	a. Introduction to CDIO b. Lab Tour	To introduce CDIO fundamentals to novice faculty members, and address implementation aspects to faculty experienced in the CDIO approach.
Session 3	Formulating learning outcomes (presentation)	To introduce systematic methods to connect courses with programs through the intended learning outcomes.
Group Work 1	Design learning outcomes	To design and develop appropriate learning outcomes of a course with respect to making deliberate contributions to a program.
Session 4	Effective course design (presentation)	To introduce the constructive alignment between the course activities and the outcomes of the courses, and inspire the design of innovative learning activities.
Group Work 2	Design learning activities	To design or revise existing learning activities of the participant's own course.
Day 2		
Case Study 2	Assessment in product design course	To showcase an example of assessment technique from a large project-based course.
Session 5	Assessment development (presentation)	To provide theoretical insights and techniques for the development of assessment.
Group Work 3	Re-design of assessment	To apply modern assessment techniques to re-design participants' own course.
Group Work 4	Popular presentation preparation	To summarize the ideas that participants have developed, applicable to their own course.
Session 6	Final Presentation and Feedback	To present and discuss participants' planned developments of their own course.

KJ Analysis

KJ analysis is a method for understanding and developing a thematic relationship from an abstract data set (Plain, 2007). The analysis was performed by two members (the two first authors). First, they individually reflected on the themes featured in participants' final presentations and produced a set of post-it notes on a whiteboard. Then they silently re-arranged the notes into groups. After this, the members discussed and developed thematic names for each group. Finally, the groups were re-arranged to form larger sets. Figure 1 depicts the final themes that emerged from the analysis.

Based on the analysis, the three main themes that emerged were in accordance with the sections in the course, learning objectives, teaching and learning activities, and assessment. For the *learning objectives*, the main changes that the participants will make are to include clear general and specific learning objectives, clear formulation of the learning objectives within the course and clear connection between the program's and the courses' learning objectives. Regarding the *teaching and learning activities,* the main additions or changes to participants' courses will be the non-traditional content delivery, the intention to increase student motivation

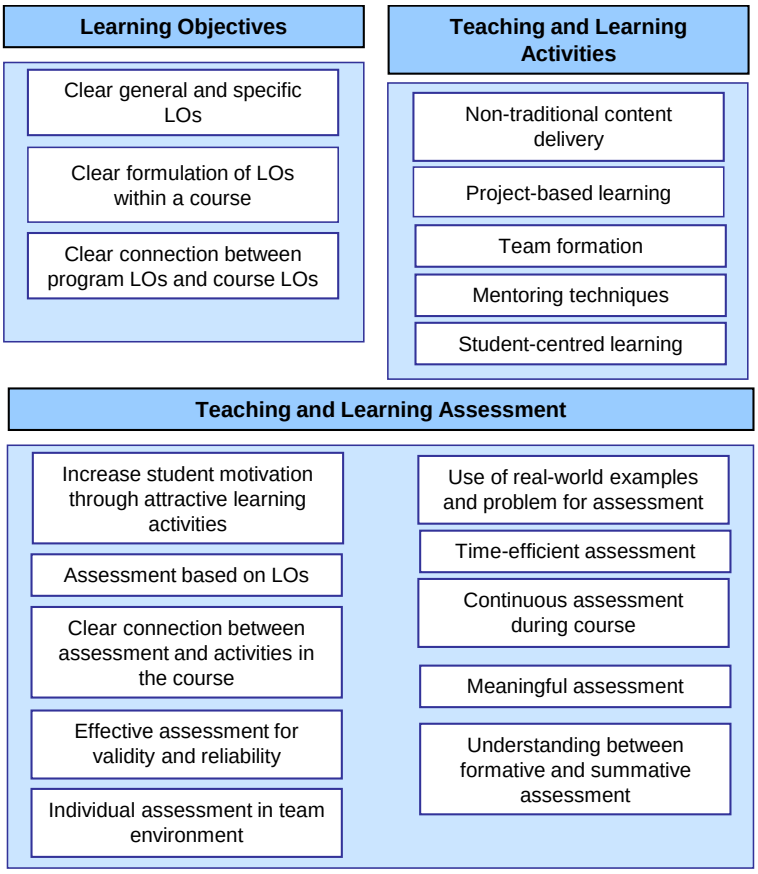

Figure 1: Result of the analysis performed on the participants' final presentation.

through engaging learning activities, the focus on student-centred learning, the use of project-based learning and the use of real-world examples and problems. Some of the participants will also try mentoring technique during teaching and will adjust the way the teams are formulated. Regarding the *assessment* theme, which was found to be most reflected, the main concepts that appeared are the use of meaningful and time-efficient assessment techniques based on learning objectives, the understanding between formative and summative assessment, the ways of individual assessment in team environment, the continuous assessment during course and the effective assessment assuring both validity and reliability.

Results from Interviews

Three course participants were interviewed. They were asked to give feedback on the course content and organization as well as on how they had utilized the information they received. All three were relatively new to the CDIO approach, and in the second session in the schedule, they chose the introductory course instead of the lab tour (see Table 1). Two of them were post-docs (A and B), and one was an associate professor (C). The courses under

consideration by different interviewee were: A - Communication Network Analysis, B - Supply Chain Management, C - Signal Processing Measurement and Applied Control for Automotive System. The topics covered during the interview were their motivation for participating, the most useful information for them in the course and what they plan to change in their own course, and finally, their opinion about the course format and suggestions for improvement.

Motivation for participation: The motivation for participation in the course varied between the interviewees. The first postdoc (A) wanted to improve the quality of her teaching and change the teaching methods of her theoretical course to be more motivating and engaging for the students. The second postdoc (B) was interested in understanding how the teaching is conducted in an engineering environment and how he could merge his own business background with the skills they want their students to learn. The associate professor (C) wanted to create a new course on the Master and Ph.D. level, and she participated in the CDIO course to develop her course based on the CDIO philosophy.

Reflection of the course content: Regarding the content, all three enjoyed the faculty course and found it overall useful as it was complementary to their formal pedagogical education at their home university. For A, the parts of the course that were the most useful were the examples in the mechanical engineer program study case, e.g. how to use MATLAB coding, and the guides of how different teaching or assessment methods work in practice, e.g. how to use specific examples to explain more theoretical and advanced concepts, and what were their results. Changes that A is going to implement are the introduction of short problems at the beginning of each course to make students think and not until after they have tried, to give them the theoretical parts and oral assessment when feasible. B found the case studies to be the most useful element. He does not currently have his own course, but he took the opportunity to reflect on the information, take a step back and look at his role in the classroom and not only the students' role. He reflected that there are things they take for granted and they need to reflect upon. His changes in the course he is involved would be to include continuous assessment and more seminars and assignments instead of lectures to activate students' independent learning. C appreciated the holistic approach of CDIO concept. For her, the most exciting and relevant part was the continuous learning approach where one concept evolves throughout the years in different courses and levels and when students graduate they build up the knowledge without perhaps realizing it. C similarly to A appreciated the detailed examples especially on how to make grading easier. She also liked the comparison between formative and summative assessment and how to connect it with the learning objectives.

Format of the course: For all of them it was the first time they attended a faculty course with such condensed format and volume of information. They preferred this format compared to spread ones where the activities are carried during a longer period. They mentioned that the activities complemented well the things they were taught and there was a good mixture of presentations where they were introduced to the idea, a time to work on their own and discuss and then present their ideas and get feedback from the audience which was very relevant. All of them found the interactions with the other participants during the group work and presentations useful. They thought that it was beneficial to have the possibility to discuss with others and get their experiences, how they are working, what they are doing, whether they are applying those ideas, or they are new to it. C also mentioned that it was very nice that the group leaders came to the rooms and made the discussions vivid. Regarding the final presentations, A mentioned that although they were useful, the time-schedule should be stricter. B also thought that they were useful since they formalized the things that they learned in a structured way. They also stayed alert throughout the course since they needed to create an outcome of the discussions and present it. B also liked that it was more interactive than just listening.

Improvements for the next course: Regarding their suggestions for improvement they generally thought that the content was sufficient. A mentioned that she would like more examples, especially on how to maintain students' attention. B would like a continuation of the course for the next period. Additionally, he thought it would be useful if credits were given, but that was not his main priority. He would also prefer some additional pre-preparation for the course, for instance, some relevant scientific articles or papers from the CDIO conference, to start thinking about his own input to the course in advance. C suggested to include more details about how a project-based course worked during the case study. She would also like an infographic of the CDIO method as a quick reference. She thinks we should follow up after a period and ask participants what they have implemented from the course and how it worked and provide that information in an upcoming faculty course.

In general, all of them felt engaged. A liked that the speakers were experienced in their area, and energetic. She mentions "*it is nice to see people who are trying to increase the quality of the education and are enthusiastic because you do not feel alone. It was also nice that I could get help from them*" and she continued that in the past she wanted to improve things, but she did not get support. C mentioned that after the workshop she shared the material with her research group and they were interested and asked her to present the ideas. Additionally, they liked the refined version of her course with its connection to their courses, and she will present it to her colleagues in department level.

DISCUSSION

Based on the feedback from the first round of the faculty development course (Bhadani et al., 2017), the second version of the course was given in a more active workshop format, including the dedicated time after each theoretical session for discussions with peers and own course development. Although the motivation for participation in the course varied between the three individuals, the new course design was very well received as can be noticed by the interviews. Based on the results, it can be argued that creating an interactive environment together with purposefully aligned sessions is a useful ingredient in such course organization. Furthermore, creating active engagement by the instructors, providing content-specific feedback is found to be appreciated, which is in line with the finding from Dolmans et al. (2002).

As it can be observed by the KJ analysis, the main themes covered all the topics, the learning objectives, teaching and learning activities, and assessment techniques. The topics which were found to be most useful varied widely among the participants as it depends on their personal experiences, their course responsibilities (e.g., postdoc, associate professors), and the strengths and the weaknesses of their own course. Therefore, we believe that it is necessary to have a holistic approach to the choice of topics to assure a uniform level across participants.

In particular, the participants found the topics related to the development of learning assessment within a course to be most used as it can be reflected from KJ analysis. The interviews' results also indicate that there are usefulness and demand in the development of continuous assessment activities within a course. This could indicate that there exists a knowledge gap, or a particular need, to develop time-efficient and effective assessment activities.

The participants used the information received during the course in three main ways: to spread the knowledge and inform their colleagues about the methods and tips they learned, to make improvements in their existing courses, or to refine and promote their new course proposal. The future work is to contact the participants of the course after one year and

evaluate if and to what extent they have implemented the changes in their courses and how satisfied they are with the results, what worked and what did not. Another aspect to be investigated is how this faculty development course could be integrated with existing pedagogical courses for faculty to assure its continuous and sustainable implementation.

CONCLUSION

The second version of the faculty development course at Chalmers University of Technology was focused on the implementation of the CDIO approach in the participants' own courses. The structure of the course in the workshop format was highly appreciated by the participants who felt engaged. The course was designed to suit both experienced and novice faculty. The course offers sessions alternating theory and practice, which seems to have increased the direct usefulness and impact on the participants compared to a previous version of the course. A holistic approach to teaching CDIO with appropriate case studies, mentorship and active engagement, with direct usefulness of the course, is recommended for future execution of such course. Further, follow up with the course participants is needed to ask a question regarding the actual implementation carried on and their insights from it. Future work will be directed towards further improving and expanding the course for larger audience.

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