IS THE CDIO JOURNEY WORTH IT? – AN ANALYSIS OF EUROPEAN INTERMEDIATE CDIO MEMBERS

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ABSTRACT

The CDIO initiative started in 2000 with four institutions. Since then the number of institutions has increased and today there is more than 160 using CDIO in their programs. This increase shows that the CDIO initiative provides something that the engineering programmes, schools, faculties, and institutions are seeking. When institutions apply for membership in the CDIO initiative, they submit an application where they answer several questions reflecting their situation, aims and goals. In the application phase, they look into the future and try to elaborate on the effects they think CDIO might provide and on the effects that they hope CDIO will bring. Furthermore, the universities do a CDIO self-evaluation as part of the application procedure. The authors of this paper have application data of more than 60 institutions starting from 2010 until today. The data is available as both authors act as regional leaders of CDIO in Europe. As the application phase is more or less a description of dreams towards a CDIO future, the authors wanted to study how well the dreams have come true and what have happened after the introduction of the CDIO approach. For this research, we selected six case universities and asked them to reflect on their journey from the application phase to today. The cases represent different countries within the CDIO European region, and they have been members of CDIO over three years. The research focused on three areas: fulfilment of expected outcomes of joining the CDIO initiative, barriers and enablers for changes and usability of CDIO self-evaluation. The results show that universities have fulfilled their expectations very well, and the CDIO approach has benefited them in various ways, and the CDIO journey is worth doing.

KEYWORDS

Join CDIO, Application process, Experiences, Standards 1-12

INTRODUCTION

The CDIO initiative started in 2000 with four universities, in 2011 there was already 62 universities, and today there are more than 160 universities. The rising number of universities in CDIO shows that the initiative provides something that the engineering

programmes/schools/faculties/universities are seeking. Earlier research has shown that there are a variety of reasons and expectations of why universities apply to join CDIO (Table 1).

One of the key reasons to join CDIO is observability which can be understood as learning from the others, sharing own experiences, visibility and availability of information about CDIO, and becoming a member of a network of universities sharing the same idea of education development. Another major reason to join CDIO is the CDIO initiative's compatibility with the university's own vision on education development and with the development actions already taking place. The third major category of reasons to join CDIO is the relative advantage universities are looking to achieve through CDIO initiative. Universities see the CDIO initiative as suitable and superior for engineering education. They are looking for a remarkable impact on their programs and overall development. Furthermore, the universities see that the CDIO initiative is not a complex system rather it can be easily understood and tools such as the CDIO standards and the CDIO syllabus are simple to use. (Kontio, 2017)

Table 1. The key characteristics of the CDIO attracting new universities (Kontio, 2017).

Characteristic	Key characteristics of the CDIO approach
Relative advantage	Suitable and superior for engineering education Remarkable impact on the development
Compatibility	Similarity to university vision Connectivity with earlier development activities
Simplicity	Easily understood Focus on engineering education Tools for development (Standard & Syllabus)
Trialability	Inspires staff Standards and syllabus available for testing Framework for development activities Not limited to engineering education
Observability	Network to learn from the others Network to share their own experiences Visibility and availability of information Network of similarly-minded universities

The characteristic categories are based on the diffusion of innovation theory (Rogers, 1995) and the identified key characteristics of each category are based on an earlier study (Kontio, 2017) where 55 CDIO applications were analysed. One of the key reasons to join CDIO is observability which can be understood as learning from the others, sharing own experiences, visibility and availability of information about CDIO, and becoming a member of a network of universities sharing the same idea of education development. Another major reason to join CDIO is the CDIO initiative's compatibility with the university's own vision on education development and with the development actions already taking place. The third major category of reasons to join CDIO is the relative advantage universities are looking to achieve through CDIO initiative. Universities see the CDIO initiative as suitable and superior for engineering education. They are looking for a remarkable impact on their programs and overall development. Furthermore, the universities see that the CDIO initiative is not a complex system rather, it can be easily understood, and tools such as the CDIO standards and the CDIO syllabus are simple to use. (Kontio, 2017)

When universities apply for membership in the CDIO initiative, they submit an application where they answer several questions reflecting their situation, aims and goals. In the application phase, the potential applicant answer a set of questions in the so-called CDIO questionnaire. There are questions as

- Why does your university want to join the CDIO Initiative?
- How do you expect CDIO to impact these programs?

In the application phase, the universities look into the future and try to elaborate on the effects they think CDIO might provide and on the effects that they hope CDIO will bring. Also, the universities do a CDIO self-evaluation as part of the application procedure.
The authors of this paper have application data of more than 60 universities starting from 2010 until today. The data is available as both authors act as regional leaders of CDIO in Europe. As the application phase is more or less a description of dreams towards a CDIO future, the authors wanted to study how well the dreams have come true and what have happened after the introduction of the CDIO approach. For this paper, the authors selected six case universities and asked them to reflect on their journey from the application phase to today. The cases represent different countries, and they have been members of CDIO over three years. The research focused on three areas: fulfilment of expected outcomes of joining the CDIO initiative, barriers and enablers for changes and usability of CDIO self-evaluation. The results of this research provide more information on the impacts that CDIO has on engineering education and the engineering programs. This information is valuable and interesting for universities, programs and the CDIO community as well. The following sections describe the research approach, the results and finally discuss and provide conclusions.

RELATED WORK

Several authors have evaluated why institutions want to join CDIO and their benefits in doing so.

One of the first is Gray (2009) who, in 2008, focused on how CDIO institutions have used the CDIO standards as a part of their quality enhancement and the progression the 23 institutions (out of 27 CDIO members in total then) had made. As Malmqvist et al. (2015) concluded “Gray’s data suggested that many schools had joined CDIO with an already existing interest and experiences in design-implement, but also that the standards related to faculty competence (9, 10) are the most difficult to improve on (p. 3)”.

Bennedsen and Christensen (2012) interviewed key persons at four Danish engineering institutions. The focus of the interviews was to find each institution's rationale for joining CDIO. They found six factors that all institutions found enabled the CDIO implementation: “Management support”, “Evolution, not revolution”, “Common language”, “Program view”, “Competence matrix” and “Support”.

Malmqvist et al. (2015) surveyed 47 institutions in 2014 with the focus of 1) Find out what engineering programs that had implemented CDIO and 2) Evaluate the effects on outcomes, the perceived benefits, the limitations, any barriers to implementation, and ascertain future development needs. They found three main rationales for choosing to adapt CDIO; “ambitions to make engineering education more authentic”, “the need for a systematic methodology for educational design” and “the desire to include more design and innovation in curricula”.

Meikleham et al. (2018) used bibliometric data analysis to see how the foci of papers mentioning CDIO and engineering education have evolved over the years. They found 1453 papers in their searches (Scopus and Web of Science, note that this excludes the CDIO proceedings). They analysed the how often the different CDIO standard phrases were mentioned and found that "design-implement", "design implement operate", "learning outcomes" and "project-based learning" was by far the most mentioned words. This could be seen as an indication of the focus of CDIO membership. However, the focus of the articles could be on other elements of engineering education than institutional CDIO characteristics for joining and staying within CDIO.

RESEARCH APPROACH

The research approach used in this paper was a multiple case study research. Case research aims for an in-depth understanding of the context of a phenomenon (Cavaye, 1996). This research methodology was selected because the goal of the research is not to achieve statistical generalisation rather analytic generalisation (Yin, 1994). In a case study, each case must be carefully selected so that it either predicts similar results (literal replication) or forecasts contrasting results but for predictable reasons (theoretical replication) (Cavaye, 1996; Yin, 1994). In this research, a literal replication strategy was used as authors' hypothesis was that implementation of CDIO could succeed in any country and any engineering university.

Methodologically this is a descriptive case study research. A descriptive case study presents a complete description of a phenomenon within its context (Yin, 2002). In general, a case study aims for an in-depth understanding of the context of the phenomenon (Cavaye, 1996). Furthermore, a case study is well-suited to capture the knowledge of practitioners and to document the experiences of practice. The unit of analysis is the university and its experience and situation of CDIO implementation.

For this research, six cases were selected. The cases are listed in table 2. The cases were selected as equally representative, with no predetermined ideas. All cases fulfil the following criteria: 1. They were willing to participate, 2. They have been members of CDIO initiative at least three years, 3. They represent different countries, 4. They have been active in the CDIO community. Invitations to nine CDIO institutions was sent, the six choose to answer.

Table 2. The case universities

University	Country	Applied
Bauman Moscow State Technical University	Russia	2014
Blekinge Institute of Technology	Sweden	2013
CESI Graduate School of Engineering	France	2016
Gdansk University of Technology	Poland	2011
The Hague University of Applied Sciences	Netherlands	2014
Technical University of Madrid	Spain	2014

A questionnaire was used for data collection. A welcoming message and a link to the questionnaire was emailed to the university's CDIO collaborator. The questionnaire had three areas:

- Area 1: Fulfilment of the expected outcome
- Area 2: CDIO self-evaluation
- Area 3: Barriers and enablers for change.

For each case, the area 1 of the questionnaire was tailored based on their initial application some years ago. Based on the goals we could identify in their application, we asked the CDIO representative of the institution to evaluate the fulfilment of that particular goal on a five-point Likert scale. Area 2 focused on CDIO self-evaluation and we wanted to know how they have used this tool to support their CDIO implementation and what their experiences are. Area 3 should provide more understanding of why something has happened and why not: are there factors that have hindered/enabled the CDIO journey.

LIMITATIONS OF THE STUDY

Collecting data from six countries is challenging. As a viable option, we did choose to use a questionnaire with both quantitative scales and free text fields. This naturally enhances the chances of getting data but also limits the amount of data that one gets. An alternative to getting richer data could be interviewing the respondents.

In the first area (Fulfilment of the expected outcome), apart from indicating the fulfilment of their goal and how important the participant saw the five categories both when applying and now, they had the possibility of commenting on that in a free text format. There were a total of 141 elements (an element is either one goal or one of the categories now or back then). One hundred and two of these had no comments. For the rest, most of the comments were just detailing the answer to the scale (like the actual period the answer covers).

For the free text field (area two and three), the respondents did give longer answers, but the answers consist almost all of just one line. There were a total of 21 answers with 836 words of text in total (approximately 40 words on average).

RESULTS

Area 1: Fulfilment of the expected outcome

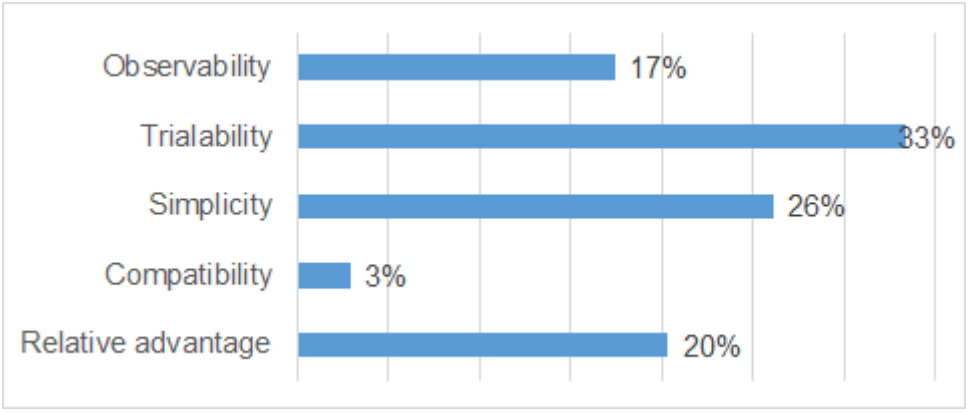
All case institutions had set (more or less) clear goals for what they wanted to happen after they had become members of the CDIO. A typical example could be a goal like "Courses with more hands-¬on learning and active student participation" or a more high-level goal like "Engineering education enhancement". In average, the institutions had 11.5 goals, spanning from 6 to 16.

We have mapped the goals to the five categories described in Table 1. The mapping was first done by one author independently, then checked by the other author and disagreements were finally discussed and a consensus established. As an example, "Courses with more hands-¬on learning and active student participation" was mapped to "Simplicity" since it focuses on the CDIO tools, whereas "Re-assess the curricula every 2 or 3 years by surveying the stakeholders" was mapped to "Relative advantage" since it has to do with quality

assurance/enhancement. The categories are based on the reasons why institutions want to join CDIO (the question “Why does your university want to join the CDIO initiative” from the application form), and this analysis is based on the entire application, so some of the more “strategic” reasons might not be identified as a concrete goal. However, as one of the authors is the inventor of the categories, he has better insight into the categorization and therefore, could give extra descriptions of the categories.

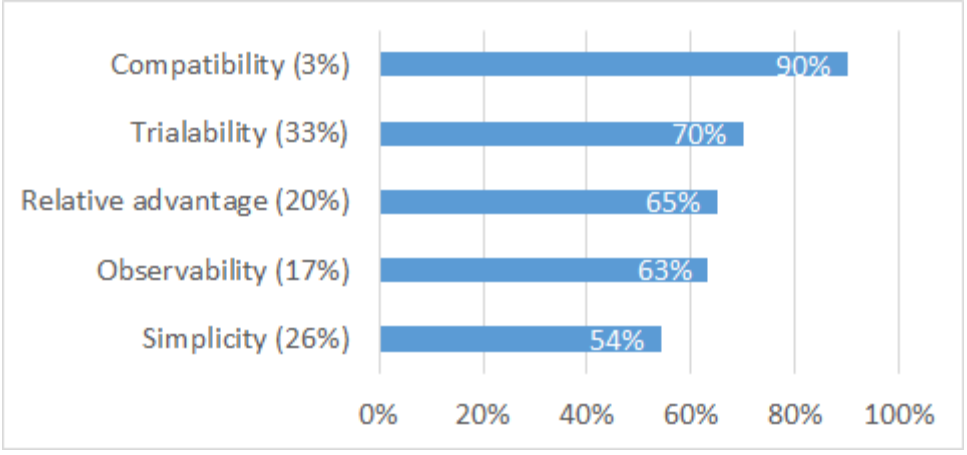
In Figure 1, you can see the distribution of the goals. As can be seen, most of them had to do with “Simplicity” or “Trialability”; most were concrete goals for programmes to implement CDIO in that program.

Figure 1. Distribution of the goals.



As described, the respondents were asked to assess the fulfilment of each goal. This varies from 0% to 100% with an average fulfilment of 64%. In figure 2, you can see the average of the fulfilment of the five categories of goals. “Compatibility” accounted for just 3% of the goals; they are almost fulfilled, whereas “Simplicity” accounted for 26%, but they are only 54% fulfilled.

Figure 2. Fulfilment of the goals.



If we look at the average of goal-fulfilment per institution, there are big differences from 39% to 84%. Looking at the number of years the institution has been a CDIO member do not

correlate with their goal-fulfilment rate, neither does the number of goals with the goal-fulfilment rate.

Area 2: Use of CDIO self-evaluation

Every case university has done at least once the CDIO self-evaluation ie. for the application phase. Three of the cases have repeated the self-evaluation after the acceptance to CDIO network and a fourth one has plans for doing it again. The remaining two cases say that they have not repeated it because

- *other reporting responsibilities do not leave time for self-assessment*
- *they are involved in accreditation programmes and have continuous improvement well monitored.*

Still, all cases found the CDIO self-evaluations beneficial. First, it makes people familiar with the standards and improves understanding of CDIO:

- *when we filled it in the first time, not everybody who did so was already familiar with the CDIO jargon.*
- *It helped us to notice that CDIO was much more than conventional active learning based on project-based activities and to see how we could improve.*

Second, the self-evaluation provides information about whether you have made progress in your development and how to continue:

- *You have to evaluate if you have any progress with your work or not (wasted money).*
- *Teams evaluated their programme on the standards. And then the outcome meant something to them, and they derived priorities from it.*
- *To see how we can better follow the CDIO standards, are very important for continuous innovation.*

Third, the CDIO self-evaluation provides a large amount of information about the programs and helps developing new programs:

- *Eight programs out of the 12 have done CDIO self-evaluation now.*
- *Self-evaluations of programs against the CDIO standards enables efficient collection of a large amount of information from many departments in parallel mode.*
- *To create two new integrated curricula with a project-based learning approach.*

Area 3: Barriers and enablers for change

All cases speak warmly about how CDIO has enabled the development of their programs. The cases evaluated for this research the importance of the key characteristics at the application phase and now. The average values of the cases are shown in table 3.

Table 3. Importance of key characteristics at the application phase and now.

Characteristic	Apply	Now
Relative Advantage	3,2	3,5
Compatibility	4,0	4,2
Simplicity	3,3	3,7
Trialability	3,8	3,3
Observability	4,0	4,3

The results show that the importance of different CDIO characteristics has slightly changed from the application phase to today. In all areas except one the importance has increased (Figure 3). The only area where the importance has decreased slightly is Trialability.

Figure 3. The shift of importance.

The areas that are influenced by CDIO can broadly be labelled as pedagogy, network, framework and accreditation. In pedagogy, the CDIO approach has influenced the way engineering education is provided

- *It has importantly supported our systematic promotion of a student-centred engineering education*
- *The active learning workshops and introductory workshops reached about 120 people of our teaching staff, who all went to work with it in their own manner and level of adoption.*

Cases emphasizing the value of the CDIO network say that

- *Shared experiences with colleagues in the CDIO meetings have been inspiring.*
- *Some programmes have started international collaborations with fellow CDIO members.*
- *And about 40 staff members have visited CDIO-meetings to learn and be inspired.*

Maybe the most valuable benefit of CDIO has the role of an engineering education framework. The CDIO initiative is said to

- *provide a well-established context for transformations that we were implementing along the last couple of decades.*
- *Be the framework which acts as a guide rail to hold on to in your process with transforming the programmes.*
- *Provide a common language over the 12 programmes of the faculty to talk about educational improvements.*

Furthermore, the CDIO tools for development have been beneficial:

- *CDIO serves as an open-source resource of new ideas, teaching philosophy, solutions of arrangements of students' workspaces, teaching methods, a template of learning outcomes.*

- *CDIO has been used to design the syllabus and integrated curricula.*
- *to conceive the new CESI engineer vision*

The role of CDIO in accreditation processes is recognised in the cases as well:

- *Interdisciplinary approach and project approach, learning outcomes taking into account competencies - all this is used now in the country's educational standards*
- *It has been positive also for national and international accreditations.*
- *CDIO has been used to prepare the accreditation's renewal.*

Finally, the cases reflected their context where they are operating with their CDIO journey. They were asked to identify possible hindrances and enablers. Many cases mentioned national regulations that set certain boundaries to their CDIO implementations, and they have to make meaningful combinations. For example, one case mentioned that they keep on asking to what extent the CDIO syllabus conforms the national goals. The national regulations also slow down the development with CDIO: *national accreditation requirements of the curriculum are very rigid.* On the other hand, it can be opposite too: *an engineering education reform is performed with the new highest education law.*

Also, the cases reported challenges within the programs such as reluctant colleagues, resources (mostly time), and not knowing the CDIO.

One positive comment based on the structure of the CDIO network was that national gaps and confrontations between research universities and universities of applied sciences are forgotten in the CDIO network. In the CDIO network, all universities are working for the same goal and it is regarded as a powerful enabler and *makes international collaboration easier than those within your country*.

DISCUSSION

Fulfilment of goals in the application

When entering CDIO, the institution had a vision of what they want to achieve by being a CDIO member. Not all of the "dreams" come true, but just one goal has not been reached at least a little bit. Institutions making many goals do not fulfil them more or less than institutions making a few goals, so we cannot advise "a good number" of goals in an application. We can speculate on the reasons for the difference between institutions, but we cannot conclude from our data.

Use of CDIO self-evaluation

The CDIO self-evaluation is a valuable tool for universities. The CDIO self-evaluation not only give information on the progress of the CDIO implementation but also helps to disseminate CDIO awareness to the programs. In faculty level, it works as a management tool as well: giving a common ground for development activities and collecting information of many programs.

Barriers and enablers for change

It is clear that CDIO has enabled positive changes in engineering education. The CDIO initiative is valued as a framework, as a network of engineering educators and as a concrete toolbox. At the same time, countries have their own educational policies and laws that either enable openness in development or build barriers limiting the freedom of going towards CDIO goals.

Implications to CDIO application procedure

The analysis of CDIO applications and goals set in the applications show a lack of real metrics to understand the impact of the CDIO approach. The goals defined in the applications are not easily measurable and it is not easy to estimate the success of CDIO. Therefore, we propose two additions to the CDIO application procedure. First, together with the goals, the application should define concrete actions for reaching the defined goals during the next 2-3 years. Second, a new step is added to the application procedure: the follow-up phase. This step is a reporting and reflecting phase where the applicant analyses their progress and challenges. The reporting could be part of the regional meeting like the new school presentations.

FUTURE WORK

As described in the section on the limitation of the study, the amount of data to be analysed is rather small and thus, the conclusions based on the qualitative data rather vague. We will like to continue this work in a more “normal” qualitative research method, namely by interviewing the relevant stakeholders. Using that approach, we expect to be able to get more in-depth data and have the possibility to start answering the more interesting question “what is the benefits and drawbacks of a CDIO journey”?

CONCLUSIONS

Is the CDIO journey worth it? Based on this study, we can answer: Yes.

We see that at the beginning, universities take the CDIO approach as a continuum with their vision and they see the CDIO approach as an easy starting point. While time goes on the relative advantage CDIO provides becomes more important as well as the network, the community of the CDIO.

We suggest that the CDIO council discusses the proposed application procedure change.

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BIOGRAPHICAL INFORMATION

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