

CURRENT AND FUTURE VALUE OF BEING IN CDIO – CDIO COMMUNITY IDEAS

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ABSTRACT

CDIO started as a project in 2000 and in 2004 CDIO initiative was formed as a worldwide collaboration in engineering education. The collaboration is built on professional networking, shared knowledge, and practices. Its members come from all over the world and share a common goal of enhancing teaching and learning in higher education. As the community grows, it is essential that we understand the expectations of the CDIO community so that the CDIO initiative, framework, community etc. can be enabled to keep itself interesting and valuable. This paper reports on a series of engagements with CDIO collaborators at the CDIO International Conference, International Working Meetings and Regional meetings that explored the rationale of working with CDIO, how we can improve the CDIO initiative, and how to keep it valuable for our collaborators. It reflects the value of being in CDIO from the viewpoint of current and potential CDIO collaborators. There is broad consensus amongst the members that CDIO provides a valuable framework for enhancing the quality of engineering education; opportunities to share, learn and benchmark their curriculum; and network with an international community of educators with similar challenges and goals. As the landscape of higher education continues to evolve, members recognize the importance of CDIO keeping up to date with changes in the world and the needs of employers. The paper will also report the challenges faced to active participation in CDIO and to communicating the value of CDIO to colleagues, decision makers, and potential collaborators. It will discuss possible steps CDIO could take to continuously develop and to be of value to both existing and potential collaborators.

KEYWORDS

CDIO membership, Value, Expectations on CDIO, Standards: all

INTRODUCTION

The CDIO website describes well the starting point of CDIO (CDIO, 2024): *Engineering education programs throughout much of the 20th century offered students plentiful hands-on practice: Accomplished and experienced engineers taught courses that focused on solving tangible problems. But as the century progressed and scientific and technical knowledge expanded rapidly, engineering education evolved into the teaching of engineering science. Teaching engineering practice was increasingly de-emphasized. As a result, industry in recent years has found that graduating students, while technically adept, lack many abilities required in real-world engineering situations.* A development project initiated in 1997 and started as a CDIO project in 2000. In 2004 the project funding ended and CDIO initiative started with the first CDIO collaborators.

Over the years the number of CDIO collaborators has grown steadily and reached 200 members in 2023 and the CDIO initiative currently has seven regions. At the same time the initiative has developed with new versions of standards and syllabus as well as introduced new elements of optional standards. The growth has brought together members from all over the world that share a common goal of enhancing teaching and learning in higher education. As the community is still growing, we must understand the CDIO community's expectations so that the CDIO initiative, framework, community etc. can be enabled to keep itself interesting and valuable. To gain understanding of these things a series of engagements with CDIO collaborators at the CDIO International Conference, International Working Meetings and Regional meetings were organized. These workshops explored the rationale of working with CDIO, how we can improve the CDIO initiative, and how to keep it valuable for our collaborators.

When CDIO was launched in early 2000 it was a new idea for improving engineering education. The CDIO approach fulfills the definition of an innovation as it is an idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 1995). The CDIO approach is actually an organizational innovation as it refers to the adoption of an idea new to the organization (Daft, 1978; Damanpour, 1996) and it is perceived new by a program, school, faculty, or university. When universities/faculties/programs/courses consider CDIO as the framework for their engineering education they go through the 'innovation-decision process'. Rogers (2003) defined this as a process (Figure 1) through which an individual or other decision-making unit passes from gaining initial knowledge of an innovation, to forming an attitude toward the innovation, to making the decision to adopt or reject, to implementing the new idea, and finally to confirming this decision. The value of CDIO can be seen differently in various phases of CDIO implementation.

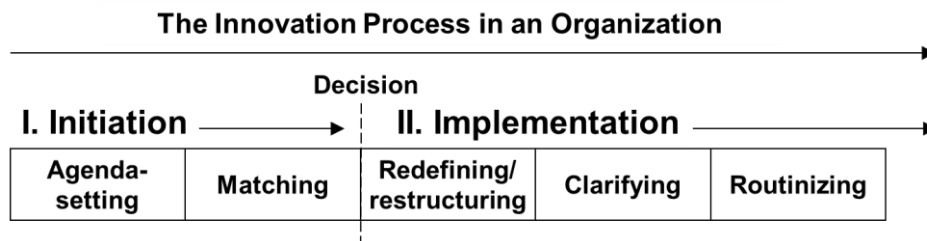


Figure 1. Innovation process in an organization.

One part influencing the adaptation CDIO approach is the characteristics of the innovation in question. The CDIO approach can offer certain value to the universities/faculties/

programs/courses going through the CDIO adaptation and implementation. Typically, an innovation can be characterized by five properties (Table 1): relative advantage, compatibility, complexity/simplicity, trialability, and observability (Rogers, 1995, 2003).

Table 1. Innovation characteristics (Rogers, 2003).

Characteristic	Description
Relative advantage	Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes.
Compatibility	Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters.
Complexity/Simplicity	Complexity/Simplicity is the degree to which an innovation is perceived as difficult to understand and use. Any idea may be classified on the complexity-simplicity continuum.
Trialability	Trialability is the degree to which an innovation may be experimented with on a limited basis.
Observability	Observability is the degree to which the results of an innovation are visible to others.

In the next section, we go through the earlier literature regarding the value of CDIO in higher education institutions. That is followed by the research approach. The results are reflected using the innovation characteristics and innovation process definitions after the research approach. Finally, the paper discusses and concludes the key findings.

LITERATURE REVIEW

CDIO started with 4 universities in 2001 and today the number of collaborators is over 200 higher education institutions, with new collaborators applying to join each year. The large number of universities worldwide that have adopted the CDIO approach suggests the applicability and viability of CDIO to different contexts and needs. What are the motivations of universities for joining CDIO? What are engineering educators looking for?

In an analysis of the application documents of 55 mainly European universities, Kontio (2017) found 3 main reasons:

1. **Observability:** The information about CDIO and its application in different contexts is visible and available. CDIO provides the universities with a community and network of similar minded universities that they can learn from and share their own experiences.
2. **Compatibility:** The CDIO approach and framework is compatible with their university's own vision on education development and with the development actions taking place.
3. **Relative Advantage:** CDIO features a systematic approach for designing and continuously improving education. It is a good model and standard for engineering education. It allows for fast and efficient re-design of programs and supports the development of quality engineering education.

Similarly, from a survey involving 46 universities from 22 countries, Malmqvist et al (2015) found that, in addition to the systematic approach for education reform, the main motivation to join CDIO were the methods for making engineering education authentic and the desire to include more design and innovation in curricula. The CDIO Syllabus and CDIO Standards are the

frameworks used by universities to re-design their curriculum and integrate the knowledge and skills required by working life. The outcomes of the CDIO implementation were positive. Most universities successfully achieved their goals for improved learning of CDIO, personal and interpersonal skills, for external recognition of educational quality like accreditation, government awards, and collaboration with other universities. There was also strong agreement among the respondents related to improvements to alumni and students' satisfaction ratings, better final degree reports or capstone design projects, graduate employability and recognition. However, the effects of CDIO implementation on student recruitment, retention and higher pay for graduates were less discernable. A deeper study of the evaluation of the long-term (5 years or more) implementation of CDIO in their curriculum by Pick et al (2021), Cheah et al (2013), Martins et al (2013) and Malmqvist et al (2010) found similar results. On the other hand, Edvardsson Stiwne and Jungert (2007) found that students from CDIO-based curricula found themselves more prepared for the job market than students from non-CDIO-based curricula.

In the studies above, the successes of CDIO implementation were attributed to

1. Factors relating to university and management like the alignment of CDIO with the university's vision and strategy, strong management support of the CDIO implementation, and the association of CDIO implementation with accreditation and national awards;
2. Factors relating to the CDIO framework and approach like focus on the professional role of engineers, ease of customization for the local context, structured yet flexible framework, a common language for curriculum design and development, and a strategy for the integration of learning of generic competencies in the curriculum; and
3. Factors relating to faculty and students like early adopters who are willing to experiment and fail, communication and sharing to get faculty buy-in, support from faculty developers, and management of student expectations, especially with regards to the importance of learning non-technical skills.

Meikleham et al. (2018), Malmqvist et al (2019) and O'Connor et al (2023) analysed the trends, directions and influence of CDIO via bibliometric data analysis of CDIO publications. All 3 authors noted that the growth of CDIO publication had reached a relatively steady state after 2011, likely in the absence of major changes in the approach. Their study also showed that CDIO papers focused mainly on active learning, integrated learning experiences, integrated curriculum, and design-implement experiences with fewer analysis on other CDIO features like faculty competence and learning assessment. They shared the same sentiments as Kamp (2021) that there is a risk of diluting the uniqueness of the CDIO initiative as a holistic framework for educational reform if there is an overemphasis on project-based learning.

While there was general agreement on the positive outcomes and value of implementing CDIO, Kamp (2021), raised the danger of CDIO, as a community of practice, "winding down", particularly when the "members feel the group has achieved its objectives or is no longer providing the value" and observed the first signs of winding down in some regions. He questioned the value of the existing focus on the CDIO syllabus and standards, its emphasis on student CDIO projects, and the sharing of CDIO implementation to experienced collaborators, especially in the evolving higher education landscape, driven by technology advancements and societal changes.

Given the trends in CDIO publications and the focus of the community, several recommendations have been made to the CDIO Initiative by the different authors. They include:

1. Renewal of the CDIO vision (Kamp, 2021; Malmqvist et al., 2015)

2. Adopt an open flexible and evolving CDIO framework considering the advances in technology and changing demands and needs of industry, society, and higher education. This would include the opportunities to incorporate blended and experiential learning, multi- and interdisciplinary studies, digitalization and sustainability (Kamp, 2021; Malmqvist et al., 2015; Meikleham et al., 2018)
3. Focus also on other “underserved” standards, like faculty development and learning assessments, besides design-implement and project work, to maintain the holistic nature of the CDIO framework for education reform (Kamp, 2021; Meikleham et al., 2018)
4. Evolve and increase evidence-based practices within engineering education to demonstrate the uniqueness of the CDIO curriculum and graduates. (Kamp, 2021; O'Connor et al., 2023)
5. Further the development of collaboration and engagement, particularly of CDIO researchers who are contributing outside the CDIO conferences and meetings, and communities in regions that are “winding down” (Malmqvist et al., 2019)
6. Connect with industry and accreditation agencies to promote the awareness and recognition of the “CDIO engineer” (Kamp, 2021; Malmqvist et al., 2015).

In conclusion, while the CDIO membership has continued to grow since the inception of the initiative and achieve the objectives of its members, it is necessary for the initiative to continue to take stock of its status quo and assess its value to its members, particularly in the ever changing and challenging environments that its graduates will live and work in.

METHODOLOGY

This paper reports on a series of engagements with CDIO collaborators at the CDIO International Conference in Trondheim, International Working Meeting in Turku and Regional meeting in Batangas. The details of these international workshops are shown in the Table 2. The series of workshops initiated from the CDIO activity plan from 2022 where the focus was originally to discuss the CDIO value among senior CDIO collaborators i.e., what CDIO can offer to universities/programs that have been CDIO collaborators several years. The discussion was very quickly broadened to define the key value of CDIO altogether.

Table 2. Series of CDIO activities on CDIO value and expectations

Location	Event	Date	Participants
Turku, Finland	International working meeting 2022	2.-3.11.2022	25
Trondheim, Norway	International conference 2023	26.-29.6.2023	27
Bulacan, Phillippines	Asian regional meeting 2023	9.-11.10.2023	90

During these workshops different questions were discussed, but in general the topics explored the rationale of working with CDIO, how we can improve the CDIO initiative, and how to keep it valuable for our collaborators. The research reflects on the value of being in CDIO from the viewpoint of current and potential CDIO collaborators.

The discussions were documented with notes taken by the authors and notes made by the smaller break out discussion groups. The documented discussions have been analyzed with content analysis. Content analysis is a research technique for systematically analyzing written communication such as the results of workshops (Weber, 1990). It allows the researcher to analyze relatively unstructured data in view of the meanings, symbolic qualities, and

expressive content (Krippendorff, 2012). In content analysis, all answers are processed, and interesting and relevant information is collected.

The collected information was reflected with the five innovation characteristics and the CDIO values were placed along the innovation process continuum.

This research had some limitations. First, the participants of the workshops cover only the input of those CDIO universities and collaborators that attended the organized workshops. At the same time a large portion of the CDIO community did not attend the workshops and their voice is not heard for this study. Second, the concept of value was not explicitly defined rather every participant approached the question from their own perspective. Third, we did not collect exact information on participants regarding their experience in CDIO community and thus we cannot compare differences between the value expectations of rather new CDIO collaborators and very experienced CDIO collaborators. We do know that the participants represented both young and old CDIO collaborators.

RESULTS

There is broad consensus amongst the members that CDIO provides a valuable framework for enhancing the quality of engineering education; opportunities to share, learn and benchmark their curriculum; and network with an international community of educators with similar challenges and goals.

The workshops' results on CDIO value focused on three main areas: CDIO as a framework, CDIO as a place to share and learn, CDIO as a community. As a framework CDIO provides an explicit syllabus and standards that give clear curriculum design guidance. The syllabus and standards are both state of the art, but at the same time living documents too. A shared view is that CDIO framework is easy to understand and adopt. The framework uses existing structures and ideas but supports enhancing the quality of engineering education. The added value of CDIO framework is keeping up to date in engineering education. The framework is seen as a tool to direct the development of engineering education and it is an institutional way to apply changes to programs. The CDIO approach promotes continuous improvement and all sides of engineering learning from theory to practice. An interesting remark was that there are already several non-engineering programs applying CDIO and that possibility of CDIO has not been communicated much.

Another value of CDIO is that it provides plenty of opportunities to share and learn from other CDIO universities/programs. Enhancing collaboration and partnerships with other institutes to learn and share best CDIO-related practices such as teaching and learning experiences are seen as major value. The annual conference and meetings provide an opportunity to learn from experienced people and gives you possibilities to guide positive change at your own university/program. There are plenty of opportunities to disseminate your own development work and receive valuable feedback and different perspectives on seemingly same challenges. The CDIO community provides you opportunities to visit top universities and explore their campuses and learning environments and take away actionable points to your own university. CDIO meetings offer possibilities to attend different introductory and advanced workshops that support your activities in implementing CDIO and developing your curriculum for example.

The third major value of the CDIO initiative is the community itself. The CDIO community consists of member universities which are represented by their CDIO contact persons and other faculty members from the faculties, schools and programs implementing CDIO. The CDIO Community is a rich arena of contacts and thus connecting people of different universities and countries. The community provides a forum for international engagement and visibility, staff development, and many potential collaboration opportunities. CDIO is described as an engaging and friendly community of practice addressing real teaching and learning issues without sugar-coating. CDIO is not a Top-Down community consisting of strategic partnerships of temporarily aligned university leaders. It has always been about the practicalities of course and program design, and the engineering competence of matriculated students. The community is an inclusive working alliance not a strategic alliance.

Although the value of CDIO seems to be clear and versatile there were several issues that the workshops raised to keep CDIO initiative interesting and valuable. One of the key things was that as the landscape of higher education continues to evolve the importance of keeping CDIO up to date with changes in the world and the needs of employers. Another topic named was to take care of continuity in universities and have several people involved in CDIO activities. Make it possible for new staff members to learn about CDIO, to join in CDIO meetings and conferences, and to have support for adopting CDIO. It was also discussed that making time for education research is essential and securing an arena to present engineering education focused research results. Furthermore, the role of management is important and therefore also the value of CDIO and the knowledge about CDIO must be confirmed and communicated to faculty deans and program leaders. Finally, issues relating to making participation possible and strengthening connections to industry and reaching our non-engineering programs were discussed too. As a global initiative, there are a lot of traveling required if you want to be active in the CDIO community. This sustainability issue together with the cost issue are challenges that need to be addressed in the CDIO community. As an engineering educator network, the relevance and connections to industry are essential, but how could CDIO initiative emphasize these in its' own activities or is it more of a questions of each university? There are already examples of CDIO value outside engineering and this could be a possibility to communicate more. Show that the value of CDIO is not only in engineering rather broader in higher education.

DISCUSSION

The values of CDIO can be reflected with the innovation characteristics and innovation-process. As the CDIO network has over 200 member institutions now and new institutions are joining all the time, it is quite clear that CDIO approach is seen advantageous and thus bringing in Relative advantage. The value discussion showed that CDIO approach is seen consistent with the existing values, goals and needs in engineering education thus CDIO as an innovation is showing Compatibility. At the same time CDIO is seen as a framework which is easy to understand and there are activities supporting the understanding and utilization of the CDIO approach (Simplicity). The core tools of CDIO (Standards, Syllabus) are freely available for testing and trying although thorough implementation and development takes time. In principle, you can say that the CDIO approach is available to try for anybody considering adopting the CDIO (Triability). The CDIO community with its' opportunities to share and learn from each other's as well as visits to different universities provides a great opportunity to observe the results of the CDIO and to stimulate peer discussion on the implementation ideas and experiences (Observability). In practice, the value of CDIO seems to fulfill typical characteristics of an innovation. The literature review showed very similar results as the

workshop discussions during this study. Same elements of CDIO as emphasized in earlier studies are still seen important and major features and properties of the CDIO initiative.

From the innovation-process perspective the value of CDIO is a bit more complex. The value of CDIO is easily seen at the Initiation part of the innovation-process including Agenda-setting and Matching stages. When an organization in this case university/faculty/program sees a performance gap in their performance and start looking possible solutions several CDIO meetings and CDIO website provide basic information for setting the agenda and matching their challenges with the possibilities in CDIO approach. The CDIO meetings and CDIO knowledge library in the CDIO website are places to learn and gain understanding of the CDIO approach as well as match suitability of CDIO to your own needs and challenges. The CDIO syllabus and standards give different perspectives to your programme and clarify the possibilities of the CDIO approach. Furthermore, there are introductory and other workshops available.

Once the organization makes the decision to start applying the CDIO approach, showing the value of CDIO becomes more challenging. In the beginning of the Implementation-part of Innovation-process at Redefining/Restructuring-phase the CDIO standards and CDIO syllabus provide concrete examples and tools on how to improve and redefine your programmes and curricula. The value of CDIO is visible as you have concrete tools supporting your development activities even though you must adapt and translate everything to your own situation and context. When the organization moves to Clarifying and Routinizing phases of the Implementation-part the value of CDIO is more challenging to notice as it is typical that the innovation loose it's special identity. Of course, the CDIO tools are there, and the organization is applying them, but the organization must keep CDIO active, visible, and recognizable after the first years too. The CDIO approach has a tool for this continuous value expression in the form of CDIO self-evaluation. The CDIO self-evaluation provides six different levels in each of the standards and thus gives the opportunity to reflect the development activities and to keep CDIO recognizable for years on. The literature review raised the challenge of keeping CDIO interesting after the typical steps with standards and syllabus has been taken. Reflecting workshop discussion with the innovation process in organizations confirms this challenge of showing the CDIO value and keeping it visible. Figure 2. tries to place the main findings relating the value of CDIO and different elements of CDIO in different phases of innovation-process.

During the workshops the attendees identified recent new activities supporting the value of CDIO. The community established a concept of working-groups at the international conference in Aarhus 2019. At the beginning the working groups were formed by participants with a common interest in a topic related to the subject matter of the conference. Some working groups have continued their work outside conferences, and some are nowadays part of the CDIO activity plan. Working groups provide an additional valuable opportunity to the CDIO community by enlarging the activities past the typical syllabus and standard focused activities. Two examples of activities that started as working groups are the Curriculum Agility and Peer-to-Peer Support. As the workshops raised the working groups as a new possibility to CDIO initiative the literature review brought back several recommendations identified earlier. Some of these recommendations have already been worked on such as the updated vision of CDIO. However, many of these recommendations still need addressing and work.

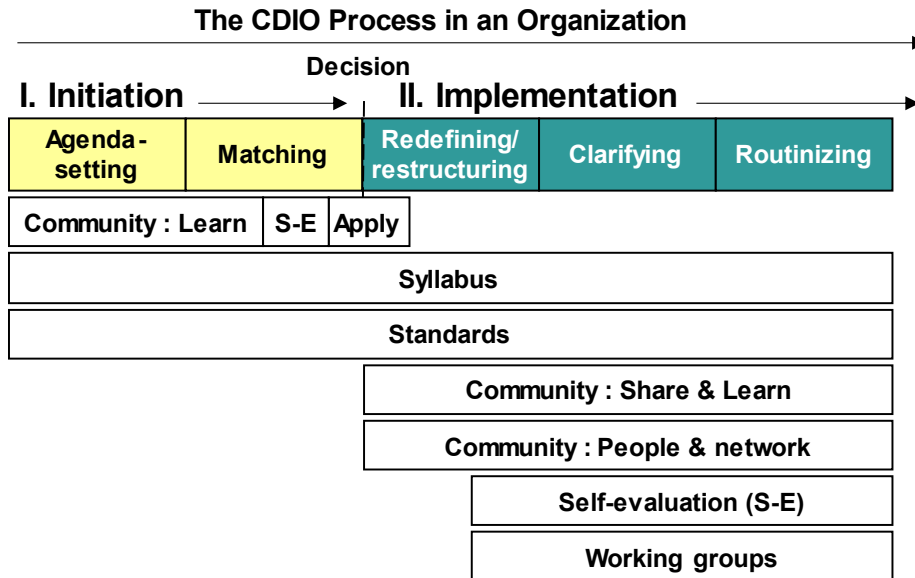


Figure 1. The value of CDIO in different innovation-process phases

CONCLUSIONS

There is plenty of evidence that CDIO has been of value to universities and their programmes. As shown from the literature as well as from the workshops of this study, there are clearly three main values of CDIO: 1) the framework with standards and syllabus, 2) opportunity to share and learn within the network and 3) the community of people and institutions. However, we must ensure that the framework keeps on updating and developing, there are opportunities to share and learn in the future too and the community is lively and active.

At the same time the study also showed that the CDIO initiative and community is not using its full potential. The potential of this large community is vast, but it seems that most joint activities are happening in our meetings and not throughout the calendar. Therefore, we must continue to encourage more collaboration into working groups and other forms of collaboration such as peer-to-peer support activity. The CDIO initiative should also ensure that all standards are equally addressed and operated within the CDIO community. The publications focus on certain standards and less information is available on for example faculty development and learning assessment. Could we establish own working groups to these? Maybe also to some of the optional standards? Altogether, we should increase research on CDIO implications and effects. We emphasize CDIO self-evaluation when universities are joining CDIO, but nobody is asking anything after universities have joined CDIO. Should we support and build a system that helps universities to continuously utilize self-evaluation as a tool for quality enhancement? Finally, CDIO as organization has limited collaboration with other engineering bodies although collaboration/communication is happening through individual persons. Could the value of CDIO be strengthened by establishing these networks and communication channels too?

To summarize, this study basically confirmed the existing knowledge and assumptions of the value of CDIO, but at the same time it raised several possibilities to further add the value of CDIO and these topics needs to be addressed at the CDIO council meetings.

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BIOGRAPHICAL INFORMATION

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