

CDIO. CAN WE CONTINUE THE WAY WE ARE?

Aldert Kamp

CDIO Co-director
Aldert Kamp Advies, The Netherlands

Immediate past Director of Education TU Delft
Immediate past Leader 4TU.Centre for Engineering Education

ABSTRACT

In 10 workshops all over the globe, about 150 CDIO community members discussed the status quo, explored the fit between the current CDIO organisation and the changing environment, set goals, and substantiated arguments for a roadmap for CDIO 2030. They formulated new mission and vision statements for the CDIO Initiative and conceived ideas for the advancement of the CDIO framework. The goal setting and strategic thinking has culminated in a proposal for more structure to consolidate the community of practice with durable engagement and stronger involvement in orchestrated experimentation and sharing of practice. A broad consensus amongst the members exists about the urgency and importance to advance the CDIO framework beyond updating the syllabus or growing in numbers. Many members expect guidance for new developments in engineering education, such as challenge-based learning, blended learning or collaborative learning in a digital environment. The lack in evidence of the impact of the CDIO Initiative is an important issue. Recognition and appreciation of the CDIO Initiative by members and the outside world requires a structured investigation and publication of the positive impact CDIO has on the competencies of the engineering graduates, professionalisation of staff and curricular and pedagogical practices. Results of such research should also be input to a continuous advancement of the initiative. A major concern is the risk that the holistic nature of the CDIO framework is diluted. Whilst the landscape of engineering education has changed significantly over the past 20 years, in the outside world CDIO has almost become a synonym for conceive-design-build-operate projects. The initiative is at a crossroads of proceeding as before, or turning the tide and lead change in the next decades.

The paper gives concise descriptions of the CDIO workshops and detailed insights in the discussions and enable you as a reader to make up your own mind. They address the status quo as perceived by the members (why we do what we do), the shift in engagement by newcomers and retirements from the community, the future outlook (who do we want to be in 2030) and the reformulation of the mission and vision statements for the CDIO Initiative. The paper gives an inventory of breakthroughs that are necessary to move CDIO back into a leadership position of innovative engineering education, if that is what we want.

KEYWORDS

Organisation; Community; Framework; Roadmap, 2030; Mission, Vision, CDIO Standard 12

INTRODUCTION

CDIO is a worldwide collaborative, formed in 2004. It is based on the commonly shared premise that engineering graduates should be able to conceive, design, implement and operate complex value-added engineering systems in a modern team-based engineering environment to create advanced systems, products and processes. The original community was formed by a core group of four institutions in two countries. They shared a common passion and need for the enhancement of higher engineering education. It has grown into a worldwide community with about 180 institutions (January 2021). Its individual members are mainly middle level engineering educators, education managers, autonomous engineering experts and people who have the ambition to become a leader or are already an emerging leader. Together they form the CDIO community of practice that has a culture built on professional networking, personal relationships, shared knowledge, and voluntary participation. The members have the common goal of enhancing, sharing good practices, developing ideas and understanding challenges in higher engineering education all over the globe. The CDIO Syllabus has been the leading guide for what engineering students should learn. Together with a set of 12 effective practices, the CDIO Standards, they form the basis for the CDIO Initiative. The community, organised in seven regions and supervised by the Council, is highly organic, informal and self-regulating by nature. It keeps things simple and informal, fosters trust and increases the shared body of knowledge. The members are empowered to design the types of interactions and determine the frequency that best meets their needs.

Communities of practice are like most living organisms (Wenger, 1998). They usually begin with an idea for a community and begin winding down when the community members feel the group has achieved its objectives or is no longer providing the value. With this in mind it is important to reflect on the progression of the CDIO Initiative over time, of which the conceptualisation began in 2001, is now in full operation and shows first signs of winding down in some regions and signs of growth and increased engagement in others.

A key parameter for the performance and engagement of self-regulating communities is goal setting (Locke & Latham, 2002). It looks questionable if the CDIO Syllabus and Standards and the lasting emphasis on student conceive-design-build-operate projects and a sharing of ripe and green examples of CDIO implementations or projects in progress, provide sufficient long-term value for community members who have joined five years or more. The goals these members had set for adapting the CDIO framework in their programme have been fulfilled, and little or no value remains. While the CDIO goals have remained the same since 2004, the landscape of higher education has changed significantly, and society, science and technology and teaching and learning are expected to accelerate change in the next decades (Kamp, 2016, 2020). If the CDIO Initiative does not only want to survive, also thrive in the long run, be on top of the world of higher engineering education, it cannot wait and adapt to change. It has to lead change and make change happen. It is therefore urgent and important to set new goals and perform a strategic analysis as input to the development of a CDIO Roadmap 2030.

GLOBAL DISCOVERY TOUR

In a series of 10 highly interactive workshops between 2017 and 2020 (Table 1) I have tried to reap the benefits of the *wisdom of crowds* (Surowiecki, 2004) and explored together with a broad representation of CDIO members what issues may impact engineering education and

the CDIO Initiative until 2030. Following a theory of goal setting (Locke & Latham, 2002) we gradually developed long-term goals, ideas for change and contributions to a CDIO Roadmap. The outcomes of the meetings in Calgary, Sunshine Coast and Moscow (2017-2018) had the aim to develop an awareness about the strengths and weaknesses and undiscovered opportunities of CDIO. Their outcomes were elaborated in depth at the International Working Meeting in Delft (2019) and integrated in new formulations for a mission and vision statement, a provisional roadmap, and a list of strategic issues, of necessary breakthroughs. Details of the map and the formulation of the mission and vision statements were revisited at the EU/UK Regional Meeting and the Asian Regional Meeting in spring 2019. The Covid-19 pandemic unintentionally made the CDIO International Working Meeting at Singapore 2019 the last meeting in the series. The discussions and analyses in Singapore focused on the necessary breakthroughs in membership, the organisational structure and the move to thought leadership.

Table 1 Series of CDIO Roadmap 2030 workshops

| Location | Event | Subject | Time | # Part. |
|-----------------------------|--|--|--------|-----------------|
| Offsite | Survey January 2017 | Role of CDIO Initiative expected in the changing world of higher education | - | 10 |
| Calgary Canada | CDIO Annual Conference June 2017 | Current state of affairs; discussions about who are we, how are we organised, what do we do and why? | 2 hrs | 40 |
| Calgary Canada | CDIO Annual Conference June 2017 | Who do we want to be in 2030: discovery of the impact on CDIO Initiative of extreme out-of-the-box utopian and dystopian future scenarios of higher education | 2½ hrs | 25 |
| Sunshine Coast Australia | CDIO Fall Meeting November 2017 | | 3 hrs | 10 |
| Moscow Russia | EU/UK Regional Meeting January 2018 | | 2 hrs | 12 |
| Delft Netherlands | CDIO International Working Meeting October 2018 | Goals setting, road ahead for the CDIO community and framework in 2030: what are we facing – what are we aiming for – what are we capable of? formulation of new Vision and Mission Statements; discovery of breakthroughs | 12 hrs | 32 |
| La Rochelle France | EU/UK-Ire Regional Meeting January 2019 | Sharpening of the Vision and Mission Statements; prioritisation and elaboration of breakthroughs | 3 hrs | 20 |
| Dalian China | Asia Regional Meeting March 2019 | CDIO as a follower or leader; stakeholder analysis: key expectations and needs | 3 hrs | 30 |
| Aarhus Denmark | CDIO Annual Conference July 2019 | Role and purpose of regions; differences in regional size and engagement | 1 hr | 10 (council) |
| Singapore | CDIO International Working Meeting November 2019 | Strategic issues: community level, size, membership; connection to non- academic world; shift in focus away from project-based learning | 7 hrs | 50 |

All workshops were prepared, delivered and processed systematically by the author, except the one in Dalian that was prepared and delivered by the other CDIO Co-director. All workshops had the same template. They were introduced by a 5 to 10 minute introduction about the status and activity flow of the day, after which the participants chose the splinter session of their specific interest, discussed in these sessions with four to eight members each, and reported back on flipcharts or whiteboards in a plenary session. The flipcharts and photos of the whiteboards were taken home and contained in a 55-page logbook. Apart from pictures of the sessions, no personal presence logging was made. The International Working Meetings in Delft and Singapore were supported by the Dutch Flatland visualisation agency. Their staff prepared templates for the assignments in the splinter and plenary sessions and helped to envision the outcomes and activate the change. The visuals they produced structured and recorded the thinking in sessions and became the centrepieces at the plenary wrap-up discussions. They are available for future work.

The first workshop in Calgary reflected on the fit between the current state of affairs and the environment: who are we, how are we organised, what do we do, and why? In six separate groups the participants analysed Community, Inspiration, Dissemination, Education innovation, Staff professionalization, and Industrial relationship.

To provoke deep thought about the future evolution of the CDIO Initiative, an investigation of neither projective scenarios (linear extrapolations of today's trends) nor prospective scenarios (back casting from a future vision) suffices. Instead the participants of the second workshop in Calgary and the workshops at the Sunshine Coast and Moscow investigated the impact on the CDIO Initiative from 10 different combinations of extreme out-of-the-box utopian and dystopian future scenarios of higher education. An example of such an extreme scenario is the combination where commercial brokers take over the educational role from higher education institutions ("professorless universities") and at the same time learning machines (AI) take over most non-routine cognitive engineering activities. Another example is a scenario where all curricula are unbundled into certified knowledge packages for personalised learning and at the same time universities have segregated into research and education universities.

At the International Working Meeting in Delft we made a discovery of strategic issues deemed necessary in the CDIO Initiative and the community structure (Bryson, 2018). We discovered strategic issues like turning points and emerging needs for the organisation, by imagining future scenarios and painting desired pictures of the future that would meet the intended needs. Thus we developed new perspectives for the CDIO community and framework. In subgroups of six to eight persons we put ourselves in the role of a CEO, an engineering student or a dean of an engineering department and imagined what these personas would expect from the CDIO community of practice and the CDIO-educated graduates in 2030. To establish a basis for a common ambition we established cover stories about major achievements of CDIO in 2030 in a prominent magazine, newspaper or other media that has great topical value and attracts considerable public interest. The combined output of the personas and cover stories enabled the participants to formulate drafts of a new vision and mission statement. The working meeting was concluded by the discovery of breakthroughs that are essential to meet the expectations from the personas, turn the virtual cover stories into reality, and take proactive measures.

The participants of the Regional Meetings of Europe/UK-Ireland in La Rochelle and Asia in Dalian sharpened the mission and vision statements and complemented, clustered and prioritised the strategic issues. Together they set the stage for the next working meeting in Singapore.

At the International Working Meeting in Singapore the new mission and vision statements were presented and used as a baseline for the development of a strategy for CDIO to become a thought leader in engineering education (again). In five splinter sessions alternative implementations were generated for the breakthroughs 'Size and organisation of the community of practice', 'Leadership to influence', 'Shift in focus', 'Sustainable institutional implementation', and 'CDIO for non-engineering disciplines'. The working meeting was concluded by a brainstorm about the process to develop a CDIO community of practice with durable engagement, better accountability and more shared practice, and a process of cyclic evaluation of the CDIO framework as a whole and the individual community members on a regular basis.

AWARENESS ABOUT THE STATUS QUO

The participants of the first workshop in Calgary established a common point of departure by reflecting on the current state who we are, how we are organised, what we do and why. The following paragraphs describe the main findings.

The CDIO community is open to the full spectrum of schools and universities in higher engineering education all over the world. It is free from cultural, religious or political issues. Tensions exist between the openness, the feeless membership with its potential risks of unlimited growth and uncontrolled quality, and the risk of a gradually waning commitment by the members. Today's CDIO is known as an evolving community of practice. The community has 182 (January 2021) member schools that are spread non uniformly over the seven geographical regions: Europe (71 members), UK-Ireland (16), Asia (47), North America (19), Latin America (19), Australia-New Zealand (8), Africa (2). As the community expands and evolves differently across the regions, it is critical to understand how to remain relevant, especially for members who have adopted the CDIO framework already for many years, and how to deal with changing expectations and different levels of engagement and commitment over time, which may be different per region. Agility to different needs and change is key.

CDIO portrays itself as a framework of tradition, design-build-implement projects and not so much about education innovation. The interest in design-build-implement projects is on the decline. A bibliometric study (Meikleham, 2018) indicates a halving of CDIO conference papers that address design-implement-operate projects since 2012. It mentions that an overemphasis on project-based learning could easily lead CDIO to become synonymous with a community of practice for project-based learning, thus facing the risk of diluting the unique value proposition of the CDIO holistic framework for educational reform. It is therefore necessary to provide evidence about the unique competency levels of graduates of CDIO programmes and inspire administrators and policy makers by referring to the methodology as modern engineering education, in which experiential learning is important. The framework has the potential, but currently misses the strength, to connect engineering education to the world of work and accreditation agencies. There is a very strong consensus across the regions that the CDIO Initiative requires very strong relationships with industry. It is the engineering business companies who know the needs and the competency attainment levels of young graduates of our schools. Although closing the full cycle, from education and

student to alumnus in industry to industrial leader, is a long game, we urgently need to evaluate CDIO graduates' performance and career routes in comparison with non-CDIO performances. For engineering business companies the lack of evidence is probably an important reason for their limited awareness of CDIO as a "brand" of engineers.

The dissemination of good practices in papers, presentations and workshops is important but does not lead to the momentum for systemic change. Today's CDIO Initiative lacks a leading profile in innovative engineering education. Nowadays the educational innovations in member institutions are often local fragmented initiatives whose results are shared at the conferences or regional meetings. There is a strong desire to transform CDIO into a community of practice where educational developments are harmonised into collaborative efforts. Also the continuous professionalisation of staff is important and the community is a rich source of experts. If we aim CDIO to develop into a leader in innovative engineering education, training in innovative methods of teaching and learning such as interdisciplinary education, online teaching, blended education, digital assessment of engineering questions, micro-credentials-for-credit, corporate learning in a digital environment, offer excellent opportunities. But they will only succeed if resources or incentives for such trainings and reskilling can be provided through CDIO membership.

WHAT IFS

Strategic thinking in the workshops of Calgary, Sunshine Coast and Moscow about combinations of hypothetical extreme scenarios of future engineering education of course could not yield a list of realistic opportunities or achievable ambitions for the CDIO Initiative. However, the process in these workshops opened the minds of the participants and resulted in many hints and guidance for the formulation of the mission and vision statements and the identification of strategic issues, the breakthroughs. Many of the participants realised we probably overestimate the change that occurs in the next couple of years, but underestimate the change that will occur in the next decades (Bill Gates quote). In the following section I have selected a representative set of concerns, opportunities and challenges that were identified when thinking and analysing the extreme scenarios of higher education. I have projected them on the themes and scenarios that were identified as projective scenarios as described in the MIT study about the global state of the art in engineering education (Graham, 2018). For sure these are realistic.

Shifting leadership in engineering education

The first scenario is about the shift of the leadership in innovative engineering education to "powerhouses" in Asia and Latin America. Because the CDIO framework has its roots in Western society, it does not fully reflect the realities of the Asian or Latin American world and risks to gradually lose its relevance on the global scale. In the workshops people came with evidence that regions, or countries within a region, are developing an own identity of the community of practice that better matches the regional needs. If the global CDIO is resilient enough it has the opportunity to combine these forces and thus lead the enhancement and innovation in engineering education in these regions. The shift to the East and Latin America has an immense growth potential for engineering education (millions of engineering students more) and the CDIO Initiative as well. Vice versa the CDIO members in other regions can harvest from the new insights and rapid developments in education in China, India and Latin America, and reap the benefits of cultural learning in these regions. Quite some participants of the workshops expect the CDIO framework has to incorporate the different contexts of the

regional traditions, culture and ethics in the Syllabus and Standards. Relationship building and maintenance with Chinese and other Asian partners and collaborators in Latin America is therefore of the utmost importance. It is clear that the CDIO framework and community of practice has to be open and easily adaptable to such rapid changes in the landscape of higher education.

More relevant and outward facing curricula

In the second scenario described by Graham, engineering curricula become more socially relevant and outward facing, and the desire to broaden student experience grows. This scenario about the rise of a more *humanitarian engineer* may open the CDIO Initiative to many new minds. The limitation to engineering disciplines has to be opened to multi- and interdisciplinary studies that link much better to designing solutions for complex societal problems than the traditional disciplinary way of thinking. We may have to tailor the framework to include more perspectives of humanities and social sciences, and call for more industrial engagement to better understand the needs and expected attainment levels of technological literacy. An interesting opportunity for CDIO was identified in striking up conversations with corporate universities that could lead to interesting cooperation between multinational industrial companies and the CDIO community of practice. Liberal arts sciences will develop into a strong influencer on our CDIO thinking. It will put more emphasis on impactful engineering with sustainability, ethics and responsible innovation. This shift is expected to happen simultaneously with the rise of machine learning in the engineering profession. Increasingly intelligent machines will support or replace the engineer in doing non-routine cognitive design, engineering and research work. This will increase the interest in graduates who not only have good working knowledge in the fundamentals in science and technology, but distinguish themselves by excellent creativity, empathy and ability to transfer knowledge to other contexts. These are facets that are still undiscovered territory in CDIO.

On-demand learning

The third scenario is about the trend of on-demand learning and the increasing desire for free choice and flexibility by the students. Today's Generation-Z engineering students are more oriented to their ambition, aspiration and future career (Twenge, 2018; Kamp, 2020). For CDIO an interesting opportunity develops in taking a consulting role for enterprises and member universities in the establishment of engineering profiles with coherent course packages or selection menus that meet personal needs. In the extreme case, CDIO could take a leading role as a broker of (accredited) course packages for credit for its community members. CDIO could also develop into a consultant for commercial brokers or platforms for online education and provide reference frameworks for engineering course content that is accredited by international accreditation agencies. The CDIO community of practice is full of experts and, in collaboration with industrial experts, in an excellent position to train faculty to operate in diffuse curricula and coach them in the role of chef de menu. The growing numbers of students who need guidance and monitoring of their individual study programme may offer another opportunity for the CDIO community. On a collaborative basis it could support students in career and study planning. It is obvious the organisation and framework has to be resilient enough to accommodate such major changes. In this respect the Covid-19 virus pandemic is a wake-up call for the future of higher education and the CDIO Initiative. The framework has to be made resilient and can no longer be a one-size-fits-all.

Need for CDIO to be agile

The variety in thoughts and ideas about opportunities, risks and threats for the CDIO Initiative will not all reach operational level in 2030. But we have to anticipate to their arrival in the coming decade. They show the urgency for the development of a strategy how CDIO should deal with changes in higher education. These will be characterized by more on-demand and personalised learning, partly online courses for credit, AI-assisted tutoring and peer learning, on-campus hands-on education, interdisciplinary education with more emphasis on societal relevance and impact than we are used to. CDIO has to make a choice to either taking a leading role in shaping this change, or just adapting to the changes. No doubt that any of these choices needs a more resilient CDIO community and framework than we are used to.

AMBITIONS

The International Working Meeting in Delft and the Asian Regional Meeting in Dalian were dedicated to goal setting and the discovery of the ambitions and expectations of the members of the CDIO community of practice. The participants teamed up in the role of a CEO of an engineering business, an engineering student, or a dean of an engineering department and then discussed for a 10-year time horizon *What do I expect from the CDIO collaborative network?* and *What do I expect from CDIO-educated engineering graduates?*

Pride and ambition

The discussions expressed pride, ambition and a desire for a prominent position in higher engineering education.

- a. CDIO Initiative: a reliable and qualified community of practice for continuous faculty professionalisation and peer-to-peer sharing of didactic methods in CDIO learning, a “broker” of lifelong learning modules for engineering professionals, consultation in the reform of curricula, a framework that can be used in the development of a national qualification framework, an inclusive network that is open to academia and business companies, engineering as well as non-engineering, with a significant positive impact on academic engineering degree programmes.
- b. CDIO-educated graduates: prepared to make a difference, mastering a good ensemble of engineering expert knowledge and professional skills, a mindset of sustainability, responsible engineering and innovation, ready for the Industry 4.0 world of work with top-notch skills in computational thinking, data literacy, systems thinking, integration of physical and cyber systems, and keen on authentic and impactful design and research problems from industries and institutes.

In another activity we established cover stories about a major achievement of CDIO in 2030 for a prominent magazine, newspaper or other media with great topical value. They provided more basis for a common ambition: *Who do we want to be in 2030?*

Influencer and springboard

At a higher abstraction level, it is our aim that graduates of CDIO degree programmes profile as future leaders of engineering businesses. We want to be an influencer and that means we have to develop into a frontrunner in engineering education, take leadership and make change happen on a global scale. We want to be a springboard for innovative higher

education and faculty development, even beyond the domain of engineering. To achieve these goals, CDIO shall satisfy the following enablers:

- i. an open mind and agile attitude to change (e.g. differentiation in roles of teaching staff, changing technologies, digital transformation)
- ii. a resilient organisation to adapt to (rapid) change (e.g. a community with different levels of engagement, regions that give the framework a local identity, special interest groups, different set-up of events like chase-the-sun workshops)
- iii. limited growth while being an open community
- iv. membership and engagement (industries, (also corporate) universities, NGOs, students, leaders, middle level engineering educators, education managers,)
- v. online visibility (exposure, PR, website, apps, online instruction materials)
- vi. benchmark of effective practices and a credit transfer matrix between CDIO partner institutes
- vii. collaboration and joint initiatives

MISSION AND VISION STATEMENT

On the basis of the ambitions in the previous paragraph, the participants of the workshops in Delft, La Rochelle and Singapore were challenged to update, rephrase and sharpen the existing vision statement (www.cdio.org):

“The CDIO™ INITIATIVE is an innovative educational framework for producing the next generation of engineers”

Rephrasing the vision statement and establishing a new mission statement for CDIO are important milestones towards the CDIO Roadmap 2030. Rethinking the vision statement should answer the question ‘where do we aim to be?’ The statement communicates the purpose of the CDIO Initiative and explains why we are an active member of the network. It is a source of inspiration, guidance and motivation for future work.



Figure 1 International Working Meeting Delft: drafting a new CDIO vision statement

The CDIO Initiative lacks a mission statement. Such statement talks about how we will get to where we want to be. It answers the question ‘what do we do, what makes us different?’ It focuses on the present, leads to the future and describes the purpose in relation to our stakeholders’ needs. Its prime audience is the CDIO community itself.

The outcomes of the discussions at the working meetings were that the vision and mission statements should amplify aspects of global coverage, ambition, leading collaborative network, developing innovative engineering education, openness, agility, the dynamic nature of the framework, aiming to improve continuously.

After lengthy and intensive deliberations and iterations in three consecutive workshops, the formulations of the vision and mission statement for the CDIO Initiative were agreed upon as follows:

VISION STATEMENT

“To be the leading worldwide collaborative network for innovative engineering education to produce responsible engineers who make a difference in the world through innovation and creative workable solutions”

MISSION STATEMENT

“Building community capacity to make an open flexible and evolving framework for the advancement of engineering education by an inclusive collaboration and a sharing of effective practices for local impact”

INVENTORY OF STRATEGIC ISSUES

CDIO Organisational structure

With the newly formulated ambitions in the vision and mission statements, and a list of impactful changes CDIO will experience in the next decade, nobody had any doubt that we cannot continue as we have done over the past 15 years. At the workshop in Delft, La Rochelle and Dalian the participants got the assignment to discover breakthroughs, turning points, that are essential to future-proof the CDIO Initiative and align the activities with the mission and vision statements and thus meet the expectations, turn the ambitions into reality and give guidance and control. Figure 2 shows an overview of the breakthroughs that were identified at the three workshops. Each breakthrough was tagged to one of 11 themes. The four themes Membership & Organisation, Regions, Thought Leadership, Marketing & Promotion were clustered into the comprehensive theme CDIO Organisation. It is expected that many breakthroughs within the CDIO Organisation will enable breakthroughs in the other themes.

CDIO products and services

Besides the CDIO Organisation, five other breakthroughs in CDIO products and services received high scores for importance and urgency:

1. the role the experts in the CDIO community should play in the lifelong learning of staff of member institutes;
2. bringing experts together for joint development of a springboard for innovations, with particular interest in the development of agile curricula;
3. sharing expertise, for instance by the establishment of temporary special interest groups, particularly with respect to online and blended learning, unbundling of curricula and dealing with micro-credentials or digital badges, and the integration of digital literacy in engineering education;
4. thought leadership about achieving durable implementation of CDIO in member institutions; developing a recognition of the CDIO graduate competencies may give it a boost at national and international level;
5. developing strong relations with leading industrial companies. Making connections with governmental agencies to use the CDIO framework for national qualification frameworks for higher engineering education (of special interest for the Asian region).

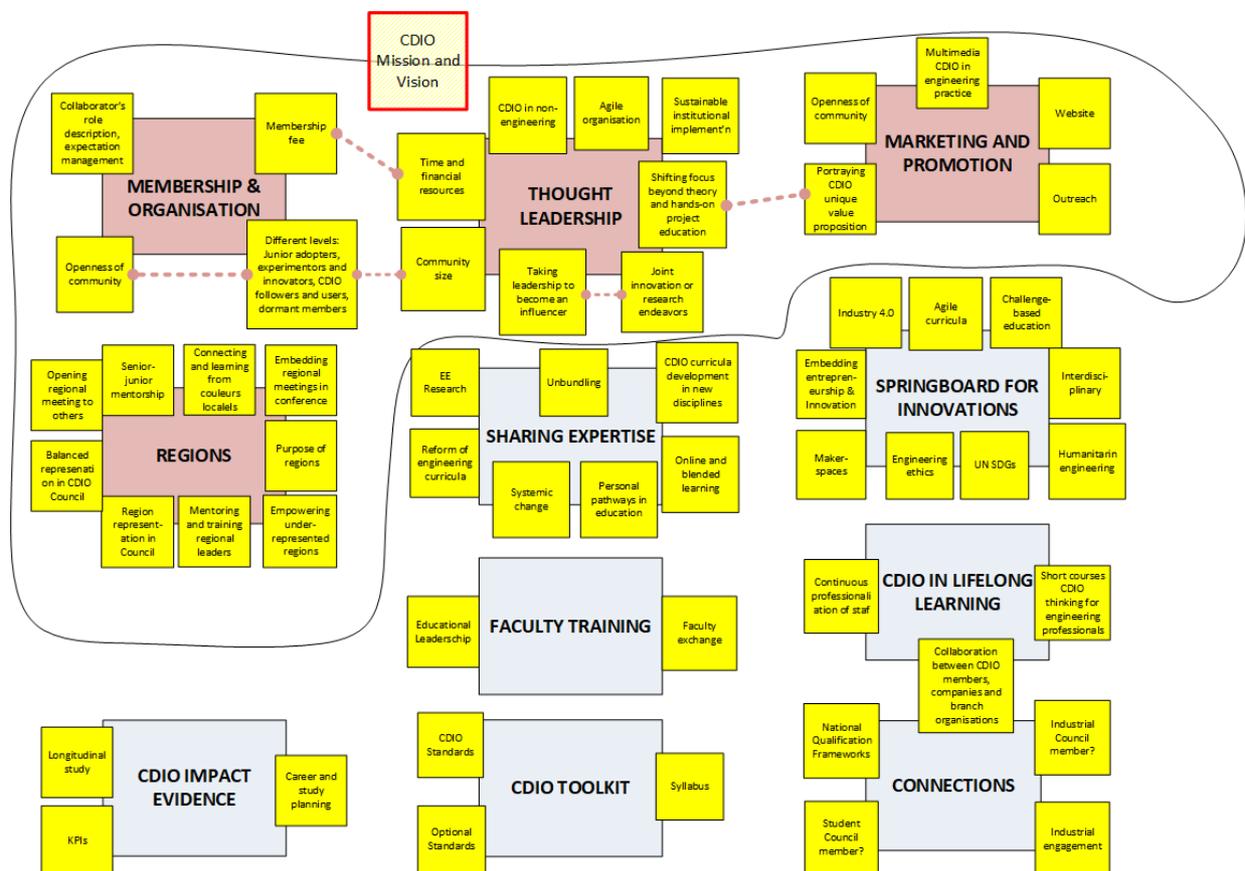


Figure 2 Inventory of breakthroughs and all kinds of facets.
The enveloping curve marks the breakthroughs in the CDIO organisation

FROM VISION TO THOUGHT LEADERSHIP

The major activity at the Singapore International Working Meeting was the development of a strategy for CDIO to become a thought leader in engineering education. In five splinter sessions the 50 participants conceived their ideas about community size, leadership to influence, shift in focus, sustainable institutional implementation, and CDIO for non-engineering. These breakthroughs were all connected to the theme of Thought Leadership (Figure 2).

Limiting the size of the CDIO community

The discussion about the community size emphasized that it is the commitment of the members of a community of practice that matters, and that commitment is often driven by the size of the community (Figure 3 left). Although the regional structure helps in this respect, the commitment in some regions has already dropped so low that even the few remaining members might consider to retire the community. The workshop participants proposed to investigate the pros and cons of different levels of membership, and relate this to better recognition and resources for innovation.

Influence and recognition

Although previous discussions resulted in a desire of CDIO to become an influencer in innovative engineering education, the workshop in Singapore refined this point of view. The added value of being a member of the CDIO community is to inform, inspire and influence the members *within the community* by evidence-based innovations, experimentation and research in education. Recognition (personal as well as institutional) is important in keeping the professional commitment alive in engaging and adding value.



Figure 3 Visualisations of the discussions about community size and shifting focus away from project-based education

In a rut of project-based education

In the discussion about CDIO being increasingly perceived by outsiders as a synonym for project-based education, the participants expressed their concerns that this perception limits and dilutes the holistic nature of the framework (Figure 3 right). It may explain the winding down of senior members in regions where other communities or associations apparently add more value to innovative educational methods that are on the horizon, such as challenge-based learning, blended learning, collaborative learning in the digital age, responsible engineering, than a CDIO membership. Although the needs and fields of interest in CDIO very much depend on the region or institution, keen interest exists in sharing curricular developments and pedagogical practices for engineering ethics, sustainable engineering, holistic engineering, integrating physical and cyber systems in engineering, etcetera. It is therefore crucial to get industries and corporate universities involved in the community. To turn the tide it is also recommended to select thought-provoking conference themes, portray them and make them leading in the paper and keynote selection, and reduce the things we have always done.

Durable membership

In the discussions about the durability of institutional CDIO membership (Figure 4 right), the following concerns about recognition of the membership were a prominent issue: the decrease in added value for institutions that have adopted CDIO for a longer period of time already, the lack of support from higher management or government. There is a clear need to acknowledge and give more exposure to the active member institutions and individual contributions. To strengthen the exposure it is desirable to facilitate individual memberships and memberships by industries, industrial branch organisations, accreditation agencies, international student bodies such as BEST (Board of European Students of Technology) and thus emphasise relevance and importance.

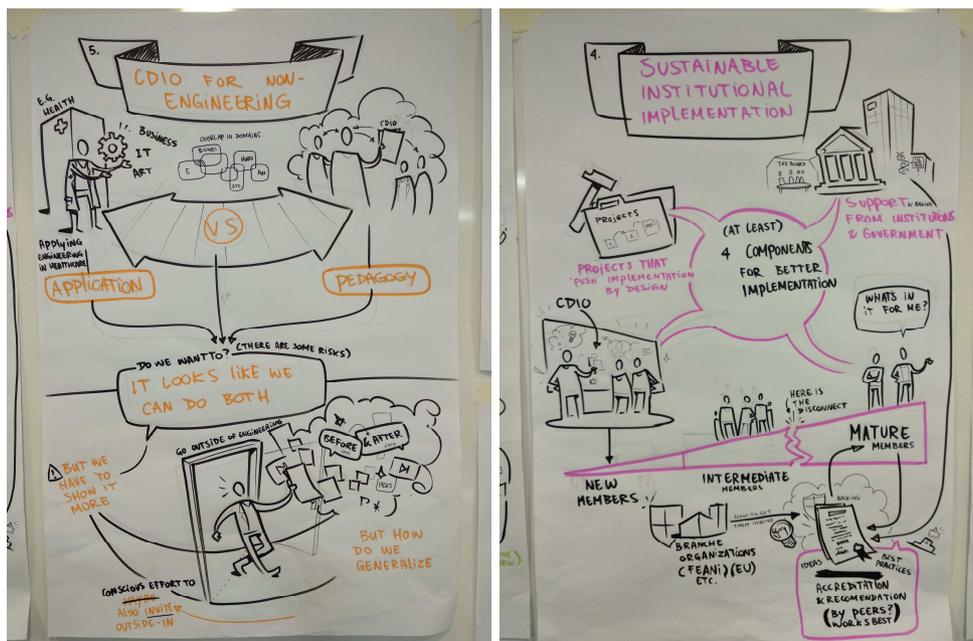


Figure 4 Visualisation of the discussions about CDIO for non-engineering and Sustainable implementation

CDIO in non-engineering disciplines

Last but not least we discussed the desire to extend CDIO to non-engineering disciplines (Figure 4 left). Evidence of the added value of the CDIO educational framework will be necessary to convince others. The pedagogy of engineering disciplines is easily transferrable to other disciplines and there is no doubt the CDIO framework is relevant for non-engineering disciplines as well. We should actively welcome non-engineering practitioners to our events and activities, inspire, not necessarily lead them, to change from engineering education point of view. It is not our aim to generalise the CDIO framework.

Summary

The plenary session after the five splinter sessions concluded that:

- A. the effectiveness of the CDIO framework and the value of being a member of the community shall be demonstrated by evidence and portrayed to the outer world, so that member institutions can take advantage in accreditation or promotion of career profiles of their graduates.
- B. The community is growing rapidly whilst the engagement in the community diminishes over time, as it no longer provides the value that is desired, or member institutions experience insufficient recognition for their contribution and engagement. Different levels of membership for a durable engagement, more recognition and accountability, and an endorsement by institutional management, should give new momentum to activities and possibly open up possibilities for funding of activities. Also an increase in diversity in membership may give a boost to engagement;
- C. There is an urgent need to strengthen the connections to the industrial and non-academic world and actively embrace non-engineering disciplines;
- D. The long lasting emphasis on project-based education as one of the assets of the CDIO methodology has become a threat for the holistic CDIO framework. Many members look forward to the next step and are eager to learn from each other about teaching ethics, sustainable design, holistic engineering, digital learning, collaborative learning in a digital environment, and the use of mindsets in engineering curricula.

RETHINKING CDIO AS A COMMUNITY OF PRACTICE AND CHANGE AGENT

The CDIO community of practice is a group of practitioners who have a common interest in engineering education. CDIO is supposed to be a place of exploration, experimentation, evaluation and reflection. In a workshop at the Singapore International Working Meeting we addressed the desire and need to rethink the rapidly growing community of practice and assure durable quality and value of the CDIO Initiative.

Organisational structure

To date the CDIO community of practice has a flat structure. Apart from the Council there is no hierarchy or differentiation in membership. Each member is part of a regional community that is coordinated by a Regional Leader who is a member of the Council. The CDIO Initiative is presided over by a 15-member Council core team that forms the heart and organises, nurtures and operates the community.

A group of 15 to 20 *active* members works closely with the Council to help shape the definition and direction of the CDIO community of practice. These members are actively engaged in defining and developing the community's shared vision, its purpose, the roles, strategies for interaction, review the applications of candidate members. They regularly attend the Online Leaders Meetings and play a vital role in the CDIO International Working Meeting and regional meetings.

The third and biggest group of the CDIO community is formed by the approximately 140 institutions that participate *occasionally* in the CDIO events. They feel a connection to the CDIO Initiative and engage on a limited basis. They mainly focus on acquiring knowledge and experience for the benefit of local development in their institution. They are members who have a more casual interest in community activities, can be newbies as well as members who consider retiring the community.

Finally there is a small group of *peripheral members*. They are the least connected to the community and only connect for instance to consult the Syllabus or Standards or provide specific consultation or service to the community. It might be interesting in future to also assign probationary members to this group: members whose application has open points, the experience and familiarity with CDIO is still low, or membership awaits for evidence of managerial support and the viability and feasibility of the sometimes overambitious plans for the transformation of curricula to meet CDIO Standards.

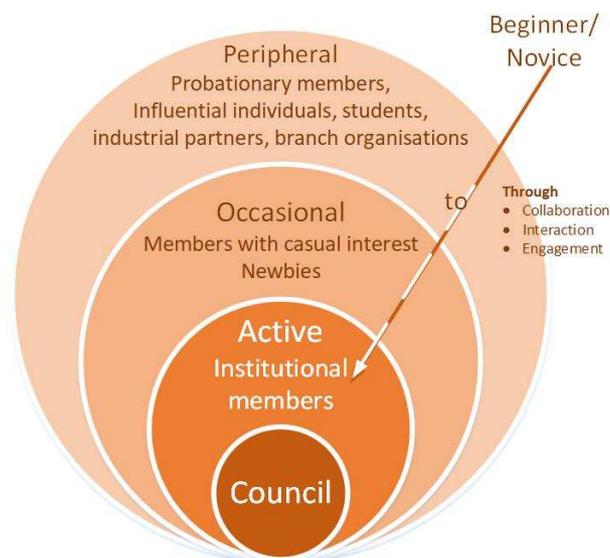


Figure 5 Community organisation with different levels of membership

In the workshop we conceived the explicit community structure shown in Figure 5. It has the goal to create more durable engagement and accountability, provide more clarity about expectations and roles, and more recognition of active members. Making this structure explicit might enable the possibility to charge a membership fee. The fees could be used for the funding of collaborative advancements by active members and stimulate active involvement by more members. Alternatively it could be used to hire a (part-time) CDIO professional for preparing or assessing peer reviews, promoting CDIO to industry or implementing any other recommendations mentioned in the Conclusions.

Using evidence to advance the CDIO Initiative

The lack of evidence of the impact of CDIO membership triggered the discussion how we might gather relevant data that would enable us to evaluate the positive impact of the CDIO framework. On the one hand we discussed the need to consult human resources professionals of engineering businesses on a regular basis. On the other hand, to stimulate growth and development, build up a history of evidence, activate the members in their role of sharing best practices, and spot candidates retiring or already dormant members, it was proposed to introduce a 6-year evaluation cycle for each member institution. The cycle should lead to a minimum of extra overhead and when appropriate, run simultaneously with a national visitation/accreditation cycle. An appropriate first peer-to-peer review for an institution would comprise of the evaluation of the impact of a curricular adaptation to the CDIO framework, a comparison with the plan presented in the membership application, and a fruitful discussion about the intentions and planning in the next period.

The making of *an evolving framework for the advancement of engineering education by an inclusive collaboration and a sharing of effective practices* (as formulated in the new mission statement) needs a trustable, transparent and uniform procedure. This procedure has to reflect that the cyclic review shall be of direct benefit for the institution and have a spin-off to the global CDIO Initiative. For the latter it is important to understand what evidence at CDIO level we are looking for and how this evidence can be collected and interpreted. The information gathered from the cyclic evaluations and reflections will be analysed at a higher aggregate level (region, global community) following a transparent process. Its goal is to identify local, regional or global needs and trends and thus give guidance to the advancement of the CDIO Initiative.

CONCLUSIONS

The CDIO community of practice is a key element of the CDIO Initiative. It is self-organising, self-regulating and its members have the freedom to determine their own level of engagement. Like most living organisms, communities of practice have a natural life cycle, and CDIO is no exception.

The need to move forward

CDIO is a holistic innovative framework for engineering education. Gradually it has become synonymous for project-based education in teamwork. For many institutional members who have adopted the framework, the value of the membership diminishes over time. Engagement shifts to regions (Asia, Latin America, Eastern Europe) where high interest exists in the enhancement of engineering curricula by adopting the CDIO framework. To avoid a winding down of interest and a retirement of member institutes, the CDIO Initiative has to advance more thoroughly than updating the Syllabus and sharing fragmented local developments alone.

In a global discovery tour of 10 workshops over the globe, new goals have been set and new mission and vision statements have been formulated. They reflect the choice and ambition of the community to *make an open flexible and evolving framework for the advancement of engineering education*. The community shall collaborate in the development and guidance of curricular enhancements and the advancement of pedagogies in engineering education that are necessary in the light of the rapid developments in technology and society. This requires

strategic thinking by the Council, clarity in responsibilities and expectations in a transparent community structure, a dedicated group of active members with commitment, and funding by its members and potentially external parties.

Recommendation 1: The Council to adopt the new CDIO vision and mission statement and develop, implement the new strategy with transparency and decisiveness in community structure, events and activities, and convey the change in message in (introductory) workshops and website, or make the conscious decision to proceed as usual.

Recommendation 2: Dare to choose and give guidance on curricular developments and pedagogical practices in engineering education that specifically reflect the changing mindset, working methods and competencies in the era of digitalisation in the world of education and technology.

The need for evidence of positive impact

The value of membership to the community of practice lies in its members. Today's flat structure and open community leads to unlimited growth in community size and untraceable involvement and engagement. To stimulate growth and development, build up a history of evidence and activate the members in their role of sharing best practices, a broad desire exists to introduce a peer-to-peer evaluation cycle for each member institution at regular intervals. A research framework and a plan for data collection and analysis have to be set up. At the highest aggregate level of the CDIO Initiative, the gathered information will be used to build up a history of evidence about the positive impact of CDIO on the quality of engineering education and its graduates. It will enable the identification of regional or global trends that give guidance to the advancement of the CDIO Initiative.

Recommendation 3: Develop and implement a cyclic peer-to-peer evaluation process by and for the members to build up a history of evidence on local and global level, and stimulate the members to share practices and improve continuously.

The need for recognition

The need for evidence, addressed above, directly relates to the high needs for recognition. Leading persons need recognition by the higher management in their institution. Active institutions want to be recognized for their contribution to the CDIO Initiative and look for ways how the benefit of a CDIO membership can be used in their national accreditation framework. There is a strong desire that the engineering competencies of the graduates of the CDIO programmes are recognized by the world of work. This can only be realised by a network of trust and quality that has strong connections with leaders and human resources professionals in leading industries, corporate universities, NGOs and accreditation agencies. A transparent community structure, a quality process for the admission and up-to-date evidence of an inclusive collaboration and sharing of effective practices are conditional for a durable recognition by performance.

Recommendation 4: Strengthen the ties with higher management and human resources professionals in leading industrial companies, corporate universities and accreditation agencies and given them the status of peripheral membership. Actively reach out to non-engineering programmes.

REFERENCES

- Bryson, J.M. (2018), *Strategic Planning for Public and Non-profit Organisations: a Guide to Strengthening and Sustaining Organizational Achievement*, 5th edition. Wiley, New York.
- Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking Engineering Education: The CDIO Approach*, (2nd ed), Springer International Publishing.
- Graham, R.(2018), *The global state-of-the-art in engineering education*; MIT School of Engineering; Cambridge.
- Kamp, A. (2016), *Engineering Education in a Rapidly Changing World: Rethinking the Vision for Higher Engineering Education*, Second Revised Edition, TU Delft, Faculty of Aerospace Engineering, Delft.
- Kamp, A. (2020), *Navigating the Landscape of Higher Engineering Education: Coping with Decades of Accelerating Change Ahead*, 4TU.Centre for Engineering Education, Delft.
- Locke, E.A. & Latham, G.P. (2002), *Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35-Year Odyssey*. *American Psychologist* 57(9):705-717.
- Meikleham, A., Hugo, R., Kamp, A., Malmqvist, J., (2018). *Visualizing 17 Years of CDIO Influence via Bibliometric Data Analysis*, in *Proceedings of the 14th International CDIO Conference*, Kanazawa Institute of Technology, Kanazawa, Japan
- Surowiecki, J., (2004), *The Wisdom of Crowds. Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economics, Societies and Nations*, Little, Brown Book Group, London.
- Twenge, J.M., (2018). *iGen, Why Today's Super-Connected Kids Are Growing Up Less Rebellious, More Tolerant, Less Happy--and Completely Unprepared for Adulthood--and What That Means for the Rest of Us*, Atria Books, New York.
- Wenger, E., (1998), *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press.

BIOGRAPHICAL INFORMATION

Aldert Kamp has been the Co-director of the CDIO Initiative since 2017. He is the immediate past Director of Education at TU Delft, the Netherlands. He has been deeply involved in the rethinking of higher engineering education with a horizon of 2030 and beyond. More than 20 years of industrial experience in space systems engineering, more than 18 years of academic teaching, educational management and leadership, and an in-depth study of trends in society, science, technology and engineering, and higher engineering education, have made him a thought-leader in future engineering education. He is the author of the thought-provoking reports *Engineering Education in a Rapidly Changing World - Rethinking the Vision for Higher Engineering Education* (2016) and *Navigating the Landscape of Higher Engineering Education - Coping with decades of accelerating change ahead* (2020). From 2014 till 2020 he was a Co-leader of the Dutch 4TU Centre of Engineering Education

(4TU.CEE) that experiments and innovates in higher engineering education. Since July 2020 he is self-employed in his one-person Aldert Kamp Advies business.

Corresponding author

Aldert Kamp
Aldert Kamp Advies
Herenweg 129; 3648 CC Wilnis
The Netherlands

www.aldertkamp.nl
me@aldertkamp.nl



This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](https://creativecommons.org/licenses/by-nc-nd/4.0/).