CDIO Standards 3.0 - Updates to the Core CDIO Standards

CDIO STANDARDS 3.0 – UPDATES TO THE CORE CDIO STANDARDS

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ABSTRACT

An effort to update the CDIO Standards from version 2.1 to 3.0 was started in 2017 (Malmqvist et al., 2017) and further outlined in 2019 (Malmqvist et at., 2019). The aims were to incorporate external changes to the context of engineering education, to address critique that had been raised against earlier versions of the standards, and to establish an extendable CDIO framework architecture. The work has resulted in that the original twelve CDIO standards, from now on named "core" CDIO standards, will be complemented by "optional" CDIO standards, that codify additional educational best practices that have been developed within the CDIO community in the same format as the original CDIO standards. This paper accounts for the changes made to the core CDIO standards. It includes the full definitions of the CDIO Standards 3.0, including descriptions, rationale and rubrics. The modifications are made to address mainly the following topics: *sustainability, digitalization, services and faculty competences*.

KEYWORDS

Sustainable development, Digitalization, Learning environments, Faculty competence, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12.

INTRODUCTION

The CDIO standards were initially introduced in 2005 (Brodeur & Crawley, 2005) and presented more extensively by Crawley *et al*. (2007). The Standards constitute a set of principles or best practices underlying the implementation of the CDIO syllabus in an engineering programme. The standards define the distinguishing features of a CDIO programme, serve as guidelines for educational reform, enable benchmarking with other CDIO programmes and provide a tool for self-evaluation-based continuous improvement.

Since 2007, the standards have been updated twice: CDIO standards 2.0 were adapted in 2014 (Crawley *et al.*, 2014) and the rubrics have been further modified (Bennedsen *et al.*, 2016), resulting in CDIO standards 2.1. These modifications have been relatively minor and have not changed the scope or the main contents of the standards.

Nevertheless, Malmqvist *et al*. (2017) pointed out that as engineering education best practice and the context of engineering are continuously evolving, also the CDIO standards must be updated. They further identified a need to address critique that had been raised against earlier versions of the standards. Malmqvist et al. (2019) further developed the ideas from 2017 into a proposal for CDIO standards 3.0. In CDIO standards 3.0, the original twelve CDIO standards, are named “core” CDIO standards, and are to be complemented by “optional” CDIO standards that codify additional educational best practices that have been developed within the CDIO community in the same format as the original CDIO standards. The proposal has been discussed in workshops at the CDIO International Working meetings in 2018 and 2019. Feedback from the CDIO community was gathered in the Fall 2019.

This paper accounts for the changes made to the core CDIO standards, and includes the full texts, i.e., including descriptions, rationale and rubrics of the core CDIO standards 3.0. An accompanying paper presents the optional standards that were recommended by the CDIO Council for development into complete versions (Malmqvist *et al*., 2020).

CORE CDIO STANDARDS 3.0

The modifications consider the following topics (Malmqvist *et al*., 2019):

- **Sustainability:** Update due to changing world (and referencing adapted Syllabus). Affects many CDIO standards.
- **Digitalization:** Update due to changing world. Affects mainly CDIO standard 6 and 8.
- **Services:** Explicitly mentioning services with products, processes and systems (because products - which we meant to include services - is often understood in a more limited sense as artifacts).
- **Faculty competences:** Widening standard 9 and 10 to address triple faculty competence: Engineering competence, Subject competence (pedagogical content knowledge, see Edström, 2017, pp 32-33), Teaching competence.

Malmqvist *et al*. (2019) further provides the full analysis of the topics and motivates the changes. Table 1 summarizes the updates to each of the standards.

Table 1. Updates to CDIO core standards in CDIO 3.0.

Std	Title	Changes
1	The Context	• Services are identified as objects for engineering development alongside with products, processed and systems *(Definition, Description, Rationale).* • Sustainability and sustainable development are mentioned *(Definition, Description, Rationale).* • Societal needs are added to customer needs *(Description).* • Recycling is included in the system lifecycle (*Description*).
2	Learning Outcomes	• Services are identified as objects for engineering development alongside with products, processes and systems *(Definition, Description, Rubric).* • Sustainable development is mentioned (*Description*).
3	Integrated Curriculum	• Services are identified as objects for engineering development alongside with products, processes and systems *(Definition, Description, Rationale, Rubric).* • Sustainable development is mentioned (*Description*, *Rationale*).
4	Introduction to Engineering	• Services are identified as objects for engineering development alongside with products, processed and systems *(Definition, Description, Rationale).* • The rationale for addressing sustainability in engineering is identified as an element in an introductory course *(Definition).*
5	Design-Implement Experiences	• Services are identified as objects for engineering development alongside with products, processed and systems *(Description, Rationale).* • The need to address sustainability and ethical aspects in development processes is pointed out *(Description, Rationale).*
6	Engineering Learning Workspaces	• Name modified to "Engineering Learning Workspaces" *(Name).* • The importance of configuring traditional physical learning spaces to support active learning experiences is stated (*Description*). • The role of digital technologies in the learning workspace is brought forward and two major text sections have been added (*Definition, Description, Rationale, Rubric*).
7	Integrated Learning Experiences*	• Services are identified as objects for engineering development alongside with products, processes and systems *(Definition, Rationale).* • Aspects of sustainable development are mentioned (*Description*, *Rationale*).
8	Active Learning	• Only linguistic modifications.
9	Enhancement of Faculty Competence*	• Faculty competence related to service development are included *(Definition, Description, Rationale).* • Faculty competence related to sustainable development is included *(Description, Rationale).* • Disciplinary knowledge and the related pedagogical content knowledge are listed as faculty competences, due to that maintaining up-to-date disciplinary knowledge may also be a concern *(Description, Rationale, Rubric).* • The concept of faculty enhancement is further elaborated to also include recruitment (*Description*, *Rubrics*).
10	Enhancement of Faculty Teaching Competence	• The concept of teaching competence and how to enhance it is further elaborated also including reference to Standards 5 and 12 (*Description*, *Rationale*, *Rubric*).

11	Learning Assessment*	• Services are identified as objects for engineering development alongside with products, processed and systems *(Definition, Rationale).* • Digital (online) assessment is mentioned alongside oral and written tests *(Description, Rationale).* • Sustainable development mentioned (Description).
12	Program Evaluation	• The need to evaluate fulfilment of optional standards, if the program has adapted any such standard, has been added *(Definition, Description).*

Standard 1: The Context*

Adoption of the principle that sustainable product, process, system, and service lifecycle development and deployment – Conceiving, Designing, Implementing and Operating – are the context for engineering education

Description

A CDIO program is based on the principle that product, process, system, and service lifecycle development and deployment are the context for engineering education. Conceiving–Designing–Implementing–Operating is a model of the entire product, process, system, and service lifecycle. The Conceive stage includes defining customer and societal needs; considering technology, enterprise strategy, and regulations; and, developing conceptual, technical, and business plans. The Design stage focuses on designing a solution to the addressed need, that is, the plans, drawings, and algorithms that describe what will be implemented. The Implement stage refers to the transformation of the design into the product, process, system, or service, including manufacturing, coding, testing and validation. The final stage, Operate, uses the implemented product, process, system or service to deliver the intended value, including maintaining, evolving, recycling and retiring. The consideration of environmental, social, and economic sustainability is an integral part throughout the lifecycle.

The product, process, system, and service lifecycle is considered the context for engineering education in that it is part of the cultural framework, or environment, in which technical knowledge and other skills are taught, practiced and learned. The principle is adopted by a program when there is an explicit agreement of faculty to transition to a CDIO program, and support from program leaders to maintain reform initiatives, visible for instance in a mission statement, or other documentation approved by appropriate responsible bodies.

Rationale

Beginning engineers should be able to Conceive–Design–Implement–Operate complex value-added sustainable products, processes, systems and services in modern team-based environments. They should be able to participate in engineering processes, contribute to the development of engineering solutions, and do so while working to professional standards in any organization. Engineers need to understand the implications of technology on social, economic and environmental sustainability factors, in order to develop appropriate technical solutions in collaboration with other actors. This is the essence of the engineering profession.

Rubric for self-assessment

5	Evaluation groups recognize that CDIO is the context of the engineering program and use this principle as a guide for continuous improvement.
4	There is documented evidence that the CDIO principle is the context of the engineering program and is fully implemented.
3	CDIO is implemented in one or more years of the program.
2	There is an explicit plan to transition to a CDIO context for the engineering program.
1	There is a willingness to adopt to a CDIO context for the engineering program.
0	There is no plan to adopt the principle that CDIO is the context of engineering education for the program.

Standard 2: Learning Outcomes*

Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, system, and service building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders

Description

The knowledge, skills, and attitudes intended as a result of engineering education, that is, the learning outcomes, are codified in the CDIO Syllabus. These learning outcomes detail what students should know and be able to do at the conclusion of their engineering programs. In addition to learning outcomes for technical disciplinary knowledge (Section 1), the CDIO Syllabus specifies learning outcomes as personal and interpersonal skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development. Personal learning outcomes (Section 2) focus on individual students' cognitive and affective development, for example, engineering reasoning and problem-solving, experimentation and knowledge discovery, system thinking, creative thinking, critical thinking, and professional ethics. Interpersonal learning outcomes (Section 3) focus on individual and group interactions, such as teamwork, leadership, communication, and communication in foreign languages. Product, process, system, and service building skills (Section 4) focus on conceiving, designing, implementing, and operating such solutions in enterprise, business, and societal contexts.

Learning outcomes are reviewed and validated by key stakeholders, that is, groups who share an interest in the graduates of engineering programs, for consistency with program goals and relevance to engineering practice. Programs are encouraged to customize the CDIO Syllabus to their respective programs. In addition, stakeholders help to determine the expected level of proficiency, or standard of achievement, for each learning outcome.

Rationale

Setting specific learning outcomes helps to ensure that students acquire the appropriate foundation for their future. Professional engineering organizations and industry representatives identified key attributes of beginning engineers both in technical and professional areas. Moreover, many evaluation and accreditation bodies expect engineering programs to identify program outcomes in terms of their graduates' knowledge, skills, and attitudes.

Rubric for self-assessment

5	Internal and external groups regularly review and revise program learning outcomes and/or program goals based on changes in stakeholder needs.
4	Program learning outcomes are aligned with institutional vision and mission, and levels of proficiency are set for each outcome.
3	Course and/or program learning outcomes are validated with key program stakeholders, including faculty, students, alumni, and industry representatives and levels of proficiency are set for each outcome.
2	A plan to incorporate explicit statements of learning outcomes at course/module level as well as program outcomes is accepted by program leaders, engineering faculty, and other stakeholders.
1	The need to create or modify learning outcomes at course/module level and program outcomes are recognized and such a process has been initiated.
0	There are no explicit program learning outcomes at course/module level nor program outcomes that cover knowledge, personal and interpersonal skills, and product, process, system, and service building skills.

Standard 3: Integrated Curriculum*

A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, system, and service building skills

Description

An integrated curriculum is based on learning experiences that lead to the acquisition of personal and interpersonal skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development (Standard 2), interwoven with the learning of disciplinary knowledge and its application in professional engineering. Disciplinary courses are mutually supporting when they make explicit connections among related and supporting content and learning outcomes. An explicit plan identifies ways in which the integration of skills and multidisciplinary connections are to be made, for example, by mapping the specified learning outcomes to courses and co-curricular activities that make up the curriculum.

Rationale

The teaching of personal, interpersonal, and professional skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development, should not be considered an addition to an already full curriculum, but an integral part of it. To reach the intended learning outcomes in disciplinary knowledge and skills, the curriculum and learning experiences have to make dual use of available time. Faculty play an active role in designing the integrated curriculum by suggesting appropriate disciplinary linkages, as well as opportunities to address specific skills in their respective teaching areas.

Rubric for self-assessment

5	Internal and external stakeholders regularly review the integrated curriculum and make recommendations and adjustments as needed.
4	There is evidence that the students have achieved the intended learning outcomes concerning personal, interpersonal, product, process, system, and service building skills.
3	The approved integrated curriculum concerning personal, interpersonal, product, process, system, and service building skills is in use.
2	The curriculum that integrates learning outcomes of personal, interpersonal, product, process, system, and service building skills is approved and a process has been initiated to implement the curriculum.
1	The need to analyze the curriculum is recognized and initial mapping of disciplinary and skills learning outcomes is underway.
0	There is no integration of skills or mutually supporting disciplines in the program.

Standard 4: Introduction to Engineering*

An introductory course that provides the framework for engineering practice in product, process, system, and service building, and introduces essential personal and interpersonal skills and the rationale of sustainability in the context of engineering

Description

The introductory course, usually one of the first required courses in a program, provides a framework for the practice of engineering. This framework is a broad outline of the tasks and responsibilities of an engineer, and the use of disciplinary knowledge in executing those tasks. Students engage in the practice of engineering through problem solving and simple design exercises, individually and in teams. The course also includes personal and interpersonal knowledge, skills, and attitudes that are essential at the start of a program to prepare students for more advanced product, process, system, and service building experiences. For example, students can participate in small team exercises to prepare them for larger development teams.

Rationale

Introductory courses aim to stimulate students' interest in, and strengthen their motivation for, the field of engineering by focusing on the application of relevant core engineering disciplines. Students usually select engineering programs expecting to learn in hands-on creative ways, and introductory courses can capitalize on this interest. In addition, introductory courses provide an early start to the development of the essential skills described in the CDIO Syllabus.

Rubric for self-assessment

5	The introductory course is regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the introductory engineering course.
3	An introductory course that includes engineering learning experiences and introduces essential personal and interpersonal skills has been implemented.
2	A plan for an introductory engineering course introducing a framework for practice has been approved and a process to implement the plan has been initiated.

1	The need for an introductory course that provides the framework for engineering practice is recognized and a planning process initiated.
0	There is no introductory engineering course that provides a framework for practice and introduces key skills.

Standard 5: Design-Implement Experiences*

A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level

Description

The term design-implement experience denotes a range of engineering activities central to the process of developing products, processes, systems and services. Included are all of the activities described in Standard 1 at the Design and Implement stages, plus appropriate aspects of conceptual design from the Conceive stage. Students develop product, process, system, and service building skills, and competences for sustainable development, in design-implement experiences integrated into the curriculum. Design-implement experiences are considered basic or advanced in terms of their scope, complexity, and sequence in the program. For example, simpler products and systems are included earlier in the program, while more complex design-implement experiences appear in later courses designed to help students integrate knowledge and skills acquired in preceding courses and learning activities. Opportunities to conceive, design, implement and operate products, processes, systems and services may also be included in required co-curricular activities, for example, undergraduate research projects and internships.

Rationale

Design-implement experiences are structured and sequenced to promote early success in engineering practice. Iteration of design-implement experiences and increasing levels of design complexity reinforce students' understanding of the product, process, system, and service development process. Design-implement experiences also provide a solid foundation upon which to build deeper conceptual understanding of disciplinary skills as well as appreciation of ethical and sustainability aspects. The emphasis on building products and implementing processes in real-world contexts gives students opportunities to make connections between the technical content they are learning, their professional and career interests, and societal needs.

Rubric for self-assessment

5	The design-implement experiences are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the design-implement experiences.
3	At least two design-implement experiences of increasing complexity are being implemented.
2	There is a plan to develop design-implement experiences at basic and advanced level.
1	A needs analysis has been conducted to identify opportunities to include design-implement experiences in the curriculum.
0	There are no design-implement experiences in the engineering program.

Standard 6:	***Engineering Learning Workspaces***

A physical learning environment that includes engineering workspaces and laboratories that support and encourage hands-on learning of product, process, system, and service building, disciplinary knowledge, and social learning, combined with a digital learning environment that includes on-line tools and spaces that support and enhance the quality of teaching and student learning

Description

Workspaces and laboratories support the learning of product, process, system, and service building skills concurrently with disciplinary knowledge. They emphasize hands-on learning in which students are directly engaged in their own learning and provide opportunities for social learning, that is, settings where students can learn from each other and interact with several groups. The creation of new workspaces, or remodelling of existing laboratories, will vary with the size of the program and resources of the institution. The physical learning environment also includes spaces like classrooms, lecture halls and seminar rooms, configured to support active learning experiences as well as traditional teaching modes. The digital learning environment employs digital learning technology to enhance the student learning experience as well as teaching effectiveness. Course development and delivery are assisted using appropriate e-learning development infrastructure. Program and course development are assisted by staff familiar with the CDIO framework for engineering education development, as well as expertise in instructional design, multimedia content development (recording, editing, and distribution), assessment and learning analytics.

Rationale

Workspaces and other learning environments that support hands-on learning are fundamental resources for learning to conceive, design, implement, and operate products, processes, systems and services. Students who have access to modern engineering tools, software, and laboratories have opportunities to develop the knowledge, skills, and attitudes that support product, process, and system building competencies. These competencies are best developed in workspaces that are student-centered, user-friendly, accessible, and interactive. The ability to augment learning activities through digital tools and resources provides instructors, program designers, and students with increased flexibility. Digital content repositories from prerequisite courses enable the efficient reactivation of knowledge, facilitating scaffolding across the curriculum. Program designers can structure student learning in a manner that provides increased learning flexibility including student mobility and personalized learning experience.

Rubric for self-assessment

5	Evaluation groups regularly review the impact and effectiveness of workspaces on learning and provide recommendations for improving them.
4	Engineering learning workspaces fully support all components of digital, hands-on, knowledge, and skills learning.
3	Development plans of engineering learning workplaces are being implemented and some new or remodeled spaces are in use.
2	Workspaces, their functionality and purposefulness for teaching are being evaluated by internal groups including stakeholders.
1	The need for engineering learning workspaces to support digital, hands-on, knowledge, and skills activities is recognized and a process to address the need has been initiated.

0	Engineering learning workspaces are inadequate or inappropriate to support and encourage digital, hands-on skills, knowledge, and social learning.

Standard 7: *Integrated Learning Experiences**
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skills

Description

Integrated learning experiences are pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, system, and service building skills. They incorporate professional engineering issues in contexts where they coexist with disciplinary issues. For example, students might consider the analysis of a product, the design of the product, as well as the social, economic and environmental responsibility of the designer of the product, all in one learning experience. Industrial partners, alumni, and other key stakeholders are often helpful in providing examples of such cases.

Rationale

The curriculum design and learning outcomes, prescribed in Standards 2 and 3 respectively, can be realized only if there are corresponding pedagogical approaches that make dual use of student learning time. Furthermore, it is important that students recognize engineering faculty as role models of professional engineers, instructing them in disciplinary knowledge, personal and interpersonal skills, product, process, and system building skills, including concepts and competencies related to sustainable development. With integrated learning experiences, faculty can be more effective in helping students apply disciplinary knowledge to engineering practice and better prepare them to meet the demands of the engineering profession.

Rubric for self-assessment

5	Courses are regularly evaluated and revised regarding their integration of learning experiences and the impact of these experiences.
4	There is evidence of the impact of the implementation of integrated learning experiences according to the integrated curriculum plan.
3	Integrated learning experiences are being implemented in courses across the curriculum according to the integrated curriculum plan.
2	Course plans with learning outcomes and activities that integrate personal and interpersonal skills with disciplinary knowledge has been approved.
1	Course plans have been benchmarked with respect to the integrated curriculum plan.
0	There is no evidence of integrated learning of disciplines and skills.

Standard 8: ***Active Learning***

Teaching and learning based on active and experiential learning methods

Description

Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on passive transmission of information, and more on engaging students manipulating, analyzing, evaluating and applying ideas. Active learning in lecture-based courses can include such methods as a partner and small-group discussions, demonstrations, debates, concept questions, and feedback from students about what they are learning. Active learning is considered experiential when students take on roles that simulate professional engineering practice, for example, design-implement projects, simulations, and case studies.

Rationale

By engaging students in thinking about concepts, particularly new ideas, and requiring them to make an overt response, students not only learn more, they recognize for themselves what and how they learn. This process aims to increase students' motivation to achieve program learning outcomes and form habits of lifelong learning. With active learning methods, instructors can help students make connections among key concepts and facilitate the application of this knowledge to new settings.

Rubric for self-assessment

5	Internal and/or external groups regularly review active learning activities on outcome-based learning across the curricula and make recommendations for continuous improvement.
4	There is documented evidence that active learning has been implemented suitably all across the curriculum.
3	Active learning methods are being implemented across the curriculum.
2	There is a plan and process to include active learning methods in courses across the curriculum.
1	There is an awareness of the benefits of active learning and it is encouraged to introduce it across the curricula.
0	There is no evidence of active experiential learning methods.

Standard 9: ***Enhancement of Faculty Competence****

Actions that enhance faculty competence in personal and interpersonal skills, product, process, system, and service building skills, as well as disciplinary fundamentals

Description

CDIO programs provide support for improving the collective competence of the engineering faculty with regards to *what to teach*, according to the full set of intended learning outcomes of the program as described in Standard 2. Faculty competence refers to personal and interpersonal skills, product, process, system, and service building skills, including concepts and competences related to sustainable development. Faculty competence also refers to the ability to support students to achieve a deeper working understanding of the relevant disciplinary fundamentals. One way to strengthen the collective competence of faculty is to take these needs into account in faculty recruitment and promotion processes. Another way is to systematically support the competence development of the existing faculty members. The nature and scope of faculty development vary with the resources and intentions of different programs and institutions. Some of these skills are best developed in contexts of professional engineering practice. Actions to enhance faculty engineering competence include: professional leave to work in industry, partnerships with industry colleagues in research and education projects, inclusion of engineering practice as a criterion for hiring and promotion, and appropriate professional development experiences at the university.

Rationale

If engineering faculty are expected to teach a curriculum of personal and interpersonal skills, and product, process, system, and service building skills integrated with disciplinary knowledge, as described for instance in Standards 3, 4, 5, and 7, they as a group need to be competent in those skills. Engineering professors tend to be experts in the research and knowledge base of their respective disciplines, with only limited experience in the practice of engineering in business and industrial settings, and its role in sustainable development. A key aspect of expertise is pedagogical content knowledge, which refers to the ability to effectively support students in learning the subject. The rapid pace of technological innovation also requires continuous updating of engineering skills. The collective faculty needs to enhance its engineering knowledge and skills so that they can provide relevant examples to students and also serve as individual role models of contemporary engineers.

Rubric for self-assessment

5	Faculty competence in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills are regularly evaluated and enhanced where appropriate.
4	There is evidence that the collective faculty is competent in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.
3	The faculty participates in competence development activities, and faculty recruitment takes into account the need for faculty competence, with regards to disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.
2	There is a systematic plan for faculty enhancement in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.
1	The need of a faculty competence development plan in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills is recognized.
0	There are no programs or practices to enhance faculty competence in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.

Standard 10: Enhancement of Faculty Teaching Competence

Actions that enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning

Description

CDIO programs take actions to enhance faculty teaching competence required for effectively creating, delivering and improving courses in the curriculum. The need for faculty teaching competence include for instance the ability to provide integrated learning experiences (Standard 7), including design-implement experiences (Standard 5) and other active and experiential learning (Standard 8), as well as assessing student learning (Standard 11) and evaluating and improving courses and programs (Standard 12). One way to strengthen the collective faculty teaching competence is to take these needs into account in faculty recruitment and promotion processes. Another way to address the need is to systematically support the development of the existing faculty members' teaching competence. The nature and scope of faculty development practices will vary with programs and institutions. Actions to enhance faculty teaching competence include: making requirements for teaching competence in hiring and performance reviews, support for faculty participation in university and external faculty development programs, creating forums for sharing ideas and best practices at the university, national and international level.

Rationale

If faculty members are expected to teach and assess in new ways, as described in the CDIO Standards, they need opportunities to develop and improve these competencies. Many universities have faculty development programs and services that might be eager to collaborate with faculty in CDIO programs. In addition, if CDIO programs want to emphasize the importance of teaching, learning, and assessment, they must recruit and promote faculty with these needs in mind, and they must commit adequate resources for faculty development in these areas.

Rubric for self-assessment

5	Faculty teaching competence is regularly evaluated and updated where appropriate.
4	There is evidence that the collective faculty has the teaching competence needed for effectively creating, delivering and improving courses in the curriculum.
3	Faculty members participate continuously in activities to develop their teaching competence, and faculty recruitment takes into account the need for faculty teaching competence.
2	A systematic plan for ensuring and enhancing faculty teaching competence is developed and budgeted.
1	A need for ensuring and enhancing faculty teaching competence is recognized and accepted within the team.
0	There are no programs or practices to enhance faculty teaching competence.

Standard 11: Learning Assessment*

Assessment of student learning in personal and interpersonal skills, and product, process, system, and service building skills, as well as in disciplinary knowledge

Description

Assessment of student learning is the measure of the extent to which each student achieves the intended specified learning outcomes. Instructors usually conduct this assessment within their respective courses. Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development, as described in Standard 2, 3 and 7. These methods may include written, online and oral tests, observations of student performance, rating scales, student reflections, journals, portfolios, and peer and self-assessment.

Rationale

If we value personal and interpersonal skills, and product, process, system, and service building skills, and incorporate them into curriculum and learning experiences, then we must have effective assessment processes for measuring them. Different categories of learning outcomes require different assessment methods. For example, learning outcomes related to disciplinary knowledge may be assessed with oral, online and written tests, while those related to design-implement skills may be better measured with recorded observations. Using a variety of assessment methods accommodates a broader range of learning styles, and increases the reliability and validity of the assessment data. As a result, determinations of students' achievement of the intended learning outcomes can be made with greater confidence.

Rubric for self-assessment

5	Internal and external groups regularly review the use of learning assessment methods and make recommendations for continuous improvement.
4	There is evidence of aligned learning assessment methods.
3	Learning assessment methods are aligned with the learning goals across the curriculum.
2	There is a plan to align learning assessment methods with the curriculum.
1	The need for the improvement of learning assessment methods is recognized.
0	Learning assessment methods are inadequate, inappropriate or not aligned.

Standard 12: Program Evaluation

A system that evaluates programs against these twelve standards and any optional standards adopted, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

Description

Program evaluation is a judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals. A CDIO program should be evaluated relative to these 12 CDIO Standards and any optional standards that it has adopted. Evidence of overall program value can be collected with course evaluations, instructor reflections, entry and exit interviews, reports of external reviewers, and follow-up studies with graduates and employers. The evidence should be regularly reported back to instructors, students, program administrators, alumni, and other key stakeholders. This feedback forms the basis of decisions about the program and its plans for continuous improvement.

Rationale

A key function of program evaluation is to determine the program's effectiveness and efficiency in reaching its intended goals. Evidence collected during the program evaluation process also serves as the basis of continuous program improvement. For example, if in an exit interview, a majority of students reported that they were not able to meet some specific learning outcome, a plan could be initiated to identify root causes and implement changes. Moreover, many external evaluators and accreditation bodies require regular and consistent program evaluation.

Rubric for self-assessment

5	There is documented evidence that systematic and continuous improvement is based on continuous program evaluation results.
4	There is documented evidence that program evaluation methods are being used with key stakeholders including students, faculty, program leaders, alumni and working life representatives.
3	Program evaluation methods are being implemented across the program to gather data from majority of including the stakeholders (such as students, faculty, program leaders, alumni, working life representatives).
2	A continuous program evaluation plan exists.
1	The need for program evaluation is recognized and benchmarking of evaluation methods is in process.
0	Program evaluation is non-existing.

CONCLUSION

The CDIO standards, originally presented in 2005 (Brodeur & Crawley, 2005), need to be continually updated in order to reflect societal needs and developments, current engineering professional practices, to capture pedagogical innovations, and to address critique of the CDIO standards.

This paper presented updates of the CDIO core standards to version 3.0, with regards to sustainable development, services, digitalization and faculty competence. These updated CDIO core standards are intended to address more clearly today’s most important engineering challenge (sustainability) and technology opportunity (digitalization). The updates further bring forward the need for “triple-competent” faculty, i.e., faculty with pedagogic, subject-matter and engineering professional competence. Future work will be needed to field-test these new standards, in program development and self-evaluation. We would like to encourage the CDIO community to document and share their experiences in order to support future development.

A parallel paper presents a set of optional CDIO Standards to augment the CDIO framework (Malmqvist *et al*., 2020). The other major document defining the CDIO framework is the CDIO syllabus. The next step is to focus on updating the syllabus, based on the analysis presented by Rosén *et al*. (2019).

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