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GUEST EDITORIAL

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Scholarly development of engineering education – the CDIO approach

The CDIO approach (Crawley et al. 2014) is a framework for the systematic development of engineering education programs. The aim is an education that supports students in developing a deep understanding of technical fundamentals and simultaneously the necessary professional skills required of a practicing engineer. The CDIO curriculum development model is based on mutually supporting subject courses and engineering projects in an integrated curriculum. Both projects and courses are sites for addressing technical knowledge together with personal, interpersonal, and engineering skills. The CDIO acronym refers to engineering practice as conceiving, designing, implementing, and operating real-world products, processes, and systems.

The CDIO Initiative (www.cdio.org) has grown from four founding members 20 years ago into a worldwide community of over 165 institutions where the CDIO approach has been adopted to support and inspire development. The network has become a lively community of practice that serves as an arena for sharing experiences on educational development activities as well as presenting scholarly advances in engineering education research. A dedicated track for Engineering Education Research was included in the CDIO conference program from 2016.

This special issue is the result of an open call for submissions reflecting on and reporting insights from experiences to improve education with the CDIO approach. They provide scholarly contributions advancing the topical research as well as inspiring further improvement of educational practices in different contexts. The eight selected articles are examples of engineering education research and development within the domains of the CDIO Initiative. We present the papers grouped under headings that highlight the different perspectives and levels that are represented in the CDIO community.

Teaching and learning – practical and epistemological perspectives

Meikleham and Hugo remind that quality feedback is crucial to learning and point out that the growth of online delivery has altered how it is obtained and shared. This article examines the nuance of informal feedback in education and how this is impacted by online delivery. Four main themes for facilitating informal feedback with online delivery were identified: (1) increased emphasis on formal formative assessment; (2) facilitating alternative 'face-to-face' experiences; (3) manual analysis of unstructured learner-generated data; and (4) automated experiences. Recommendations for course designers and implications for CDIO institutions and organisation are discussed, including blended learning projects, online communities of practice, data sharing, and advocacy opportunities.

Rådberg et al. discuss challenge-based learning (CBL), a multidisciplinary approach encouraging students to work actively with peers, teachers, and stakeholders in society to identify complex challenges, formulate relevant questions, and take action for sustainable development. They argue that CBL can be viewed as an evolution of the CDIO approach, expanding as well as deepening the learning experience. The article reports the multiple aims of a particular CBL environment that aims to combine significant student learning and societal transformation. The results show that the students perceive that they have developed deep skills in problem formulation and sustainable development,

as well as working across disciplines and with different stakeholders. Moreover, the study shows that although few student projects reach the implementation stage, there is a potential for societal impact both during and after the learning experience.

Cosgrove and O'Reilly discuss the engineering educators' tension between two epistemological worlds or realms of meaning: the technical-rational and the human-practical. Informed by experience in both design practice and engineering education, the authors agree that professional artistry is an essential dimension of both engineering practice and teaching. Advertence to this artistry elucidates the scope and limitations of technical rationality. An extended epistemology for grounding professional practices such as engineering and teaching is offered as a resource. It is argued that this epistemology implies firstly that engineering education must address design artistry, secondly that a reflective element is needed, and thirdly that for creative professionals, learning outcomes defined without due consideration of process are educationally misconstrued. Two curriculum examples from a problem and project-based civil engineering programme that address these concerns are presented.

Curriculum development and quality processes

Muñoz et al. present a case study on the process of adopting the CDIO approach for the curricular reform of a Computer Science program. The experiences were gathered through a participatory and iterative process involving the members of the program's curricular committee in charge of the CDIO implementation and self-evaluation processes, and the members of the program's national accreditation self-evaluation committee. The article provides a response to the questions on what actions effectively aid the implementation of the CDIO standards and what factors should be considered in order to successfully implement CDIO.

Bennedsen et al. discuss the tension between quality assurance and quality enhancement in engineering education. They describe and contrast existing quality assurance systems, institutional collaboration networks, as well as new innovative quality enhancement models and processes. For example, they acknowledge that accreditation processes have evolved for many years but argue that they do not necessary agilely support innovation or implement changes in educational programmes. The article reflects on a collaborative approach to quality enhancement, built on the foundations of specific pedagogical standards and rubrics (e.g. CDIO). These flexible and agile evaluation processes may facilitate incremental enhancement based on relevant needs identified collaboratively between programmes and, thus, complement formal quality assurance for engineering education.

System level curriculum models

Rouvrais, Remaud and Saveuse provide insight into work-based learning models in engineering curricula. To favour an early exposure of students to professional practice, several engineering higher education institutions have implemented integrated curricula, as proposed in the international CDIO educational framework. Based on the French national experience, this article sets out the various models of internships and apprenticeships and presents two curriculum integrations: one in a highly selective public graduate Grande Ecole and another in a private multisite engineering institution. The authors propose an extension to the CDIO framework to systematically include work-based learning as integrated activities, to better match industry requirements and student competency expectations as future engineers.

Chuchalin provides an example on the utilisation of the CDIO Standards as a means for upgrading and improving the quality of engineering education. In 2013–2016, several Russian universities became participants of the '5–100 Russian academic excellence project' and focused on the development of graduate and postgraduate engineering education. Based on the general ideas of the CDIO approach, different conceptual models for graduate and postgraduate engineering programmes were proposed and developed. The paper presents the syllabi and standards developed by analogy with the CDIO Syllabus and the CDIO Standards.

Development of the CDIO community

Edström considers possible roles for the CDIO community in the field of Engineering Education Research (EER), prompted by the start of a research track at the annual International CDIO Conference in 2016. She explores the emerging EER landscape, especially to consider whether the aim of the research is to seek knowledge to improve engineering education or to seek knowledge for its own sake. While those aims are not mutually exclusive, the priority still matters. Introducing concepts from similar debates within engineering, the paper argues for embracing the tension between usefulness and scholarliness. The EER community must also be able to evaluate work against both sets of values. A dual objective is implied: to usefully contribute to the improvement of engineering education while also establishing a recognised research field enabling sustainable careers for researchers.

The CDIO community looking forward

There is ongoing work to further develop the CDIO framework, as expressed in the CDIO Syllabus and CDIO Standards (Crawley et al. 2014). Sustainable development, in particular environmental sustainability, is already prominently featured in the CDIO approach and community. Presently, however, the United Nations Sustainable Development Goals (UN SGD) are a main influence, and the extent to which the UN SDGs are addressed needs careful examination. This will likely lead to additions or modifications of topics in the CDIO Syllabus. Similarly, the CDIO Standards will need to incorporate changes within the context of engineering education, such as digitalisation. The aim of this work is to establish an extendable CDIO framework architecture, to include recent education best practices, and also to address various forms of critique that had been raised against earlier versions. Future publications will present updated versions of the CDIO Syllabus and Standards, as well as the underpinning discussions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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