International accreditation and CDIO optional standards achievement levels at UCSC

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ABSTRACT

In this article, we describe the self-evaluation processes undergone by the UCSC School of Engineering's undergraduate programs under the CDIO standards since 2013 and show how this continuous improvement process drives the School of Engineering in 2021 to collect information related to the CDIO optional standards proposed and approved by the CDIO council in November 2019. In 2019, the School of Engineering, considering its advances and achievements, its participation in the CDIO network and the experience obtained in previous accreditation processes, decides to seek an international accreditation. Currently, we have just finished our self-assessment process to achieve international accreditation under the Washington Accord. Thus, taking advantage of the coherence between the graduate attributes defined by the agreement and our students' competencies developed considering the CDIO optional standards, The School of Engineering has collected data to assess itself and thus incorporate its short-term required training requirements. Among the main findings of our self-assessment, the programs with the highest achievement levels in Sustainable development are Electrical Engineering and Civil Engineering; in the first case, it can be explained by this competence being part of the graduate attribute profile; in the other case, by the nature of the discipline. All programs develop the Simulation-based mathematics optional standard to at least level 2, while the Geological and Electrical Engineering programs achieve level 4. Entrepreneurship and internationalization (optional standards 3 and 4) are being addressed at the institutional level by the CreoeInnovo UCSC program and through a slightly more recent UCSC Internationalization initiative launched in 2020. This work also presents an improvement plan for those programs needing improvement such as Computer Science. Implementation starts March 2022, to achieve at least level 3 in 5 years' time. We think that the optional standards should become mandatory in the short term to meet future engineers training requirements.

KEYWORDS

Standards: 1-12, optional standards, accreditation criteria, program evaluation.

FRAMEWORK

The CDIO framework includes the 12 CDIO standards and the CDIO Syllabus. The CDIO Standards correspond to best practices or principles that guide the continuous improvement of study programs, and its pillars are program philosophy, curriculum development, design-

implement experiences and workspaces, methods of teaching and learning, faculty development, and assessment and evaluation (Crawley et al., 2007). At the same time, the CDIO Syllabus provides a list of professional, personal and interpersonal skills and CDIO skills for development during the training itinerary (Crawley et al., 2011). These documents have undergone improvements to reflect recommendations and new trends until a set of 4 optional standards was proposed in 2020: Sustainable development, Simulation-based mathematics, Engineering entrepreneurship, Internationalization & mobility. Currently, we are working with the Syllabus 3.0 update.

Optional standards

Malmqvist et al. (2017) noted that, as engineering education best practices and the engineering context are continually evolving, the CDIO approach must also evolve. Furthermore, they argued that the CDIO framework could be made more flexible and open by introducing an additional category of standards, called "optional CDIO standards", to be added to the original twelve standards, now called "core CDIO standards". Since then, several proposals for optional CDIO standards have been submitted (Malmqvist et al., 2019; Malmqvist, Edström & Rosén, 2020), and the CDIO Council has decided on a process to select the proposals and work with them for possible inclusion in the CDIO framework. Thus, in 2020, 4 optional standards are incorporated 2020 (Malmqvist et al., 2020):

Sustainable development: A program that identifies the ability to contribute to a sustainable development as a key competence of its graduates. The program is rich with sustainability learning experiences, developing the knowledge, skills and attitudes required to address sustainability challenges.

Simulation-based mathematics: Engineering programs for which the mathematics curriculum is infused with programming, numerical practiced and simulation from the start

Engineering entrepreneurship: Engineering programs that actively prepare graduates for creating technology-based business ventures, to produce economic and other values for society.

Internationalization & mobility: Programs and organizational commitment which exposes students to foreign cultures, and promotes and enables transportability of curriculum, portability of qualifications, joint awards, transparent recognition and international mobility.

Washington Accord

The Washington Accord (WA), signed in 1989, is a multi-lateral agreement between bodies responsible for accreditation or recognition of tertiary-level engineering qualifications within their jurisdictions who have chosen to work collectively to assist the mobility of professional engineers. Accord signatories are committed to the development and recognition of good practices in engineering education, and their activities aim to assist growing globalization of mutual recognition of engineering qualifications. The Washington Accord is specifically focused on academic programmes dealing with the practice of engineering at the professional level (International Engineering Alliance, 2022).

Continuous program improvement at the School of Engineering

In a culture of continuous program improvement, the School of Engineering of the UCSC has voluntarily submitted its programs to multiple national accreditation processes, as shown in Figure 1. As can be seen in this figure, the Industrial Engineering, Civil Engineering and Computer Science programs have each undergone three national accreditation processes, each time increasing their accreditation periods. It is worth noting that the Chilean accreditation system assigns accreditation periods from 2 to 6 years. Currently, all five programs of the School of Engineering are working toward their accreditation under Washington Accord criteria.

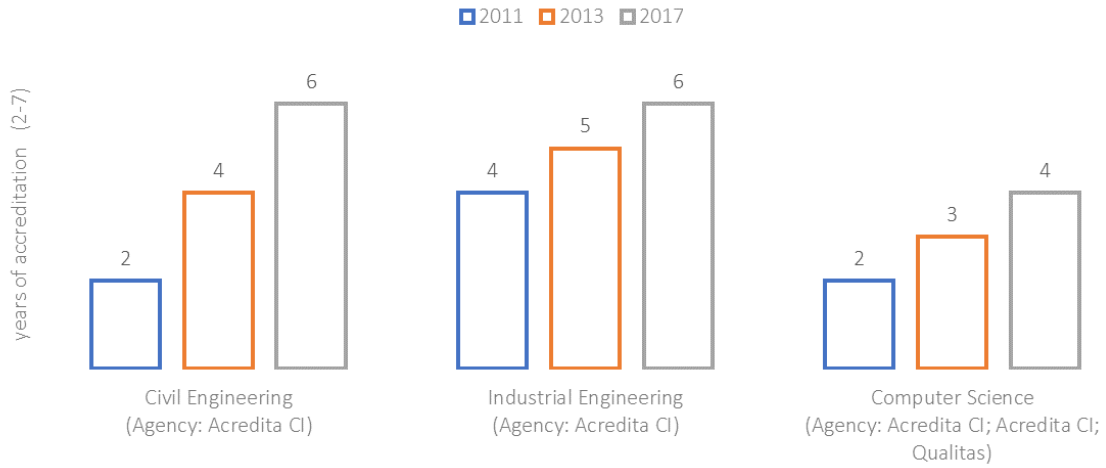

Figure 1. Increase in national accreditation periods

The School of Engineering has also been interested in self-assessing CDIO standards compliance. A preliminary global evaluation was done in 2013, which included only the Civil Engineering, Computer Science, and Industrial Engineering programs (Martínez *et al.*, 2013). Figure 2 presents these results.

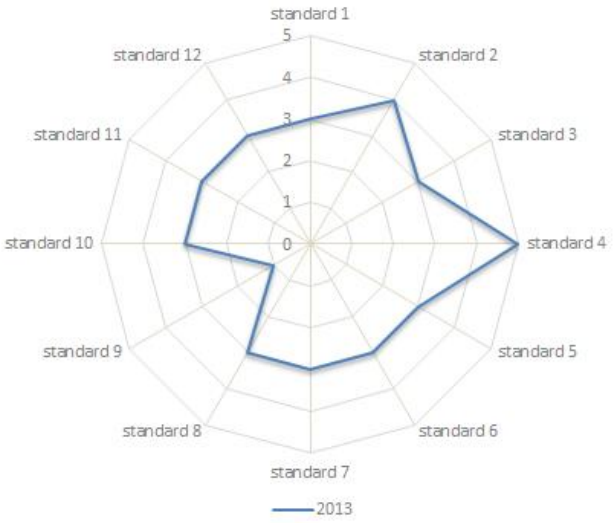

Figure 2. CDIO Global self-assessment, School of Engineering, 3 programs. (2013)

As Figure 2 shows, at that time the programs' high point was the existence of an introductory course giving students a framework for engineering practice in system building and introducing essential personal and interpersonal skills (standard 4). At the same time, the main weakness was the low level of faculty knowledge about the CDIO Initiative. To address this situation, we organized a CDIO workshop with the goal of disseminating the CDIO framework among all faculty involving in teaching engineering students, such as mathematics, physics, and part-time lecturers. As a result of this workshop, we recognized the need for a faculty competence development plan in personal, interpersonal, product, process and system building skills (standard 9). Given that the CDIO-based curricular reform had started just two years before, the levels of standards such as Design-Implement Experiences (standard 5), Integrated Curriculum (standard 3), were as expected. This self-assessment was repeated in 2015, achieving an improvement only in standard 9 (Muñoz *et al.*, 2020). Also, the Geological Engineering and Electrical Engineering programs were added in this exercise, which had begun accepting students in 2011 and 2013, respectively. Results for these programs showed that they had great room for improvement, which was largely addressed in their official curricular reforms of 2018.

Workspace improvement was addressed by building the 2,500 m^2 San José Obrero building, which includes a Structure and Geotechnics laboratory, a Hydraulics and the Environment laboratory, offices, and co-work rooms, thus promoting not only standard 6 but also standard 8. This was financed through a government-funded University Strengthening project (FIA USC 1308) and by using University funds. Standard 10 was initially strengthened by encouraging faculty to become certified through the Teacher Development Program offered by the Center for Innovation and Teaching Development of the UCSC. During the 2020 - 2021 pandemic, progress was made in aspects of disciplinary improvement (standard 9) and enhancement of faculty teaching competences by the issuance of 2 diplomas in innovation for university teaching through Laspau, an organization affiliated with Harvard University (standard 10). At the beginning of 2022, after completing the self-assessment process with a view to our international program accreditation under the criteria of the Washington accord (standard 12), we can show the progress that has been made in these years in Figure 3.

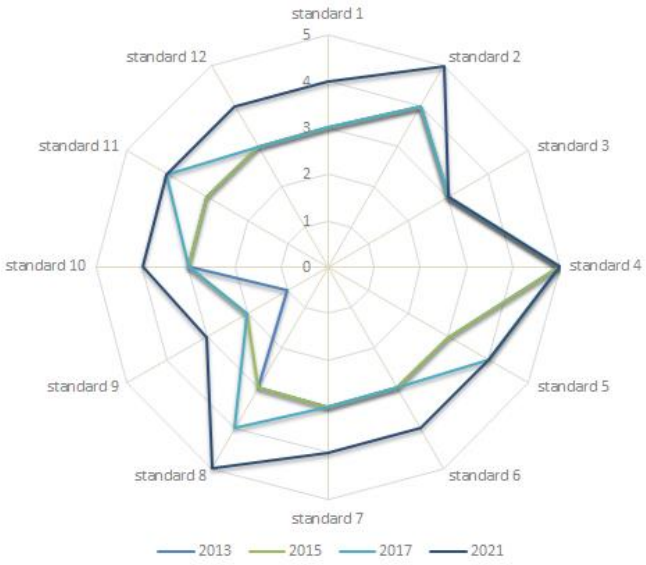

Figure 3. CDIO Global self-assessment, School of Engineering, 5 programs (2021).

Figure 3 shows a clear improvement over time in standards 2, 4, 8 and 12 related to learning outcomes, the consolidation of each program's introductory engineering course, the widespread use of active learning methodologies in both science and disciplinary courses, and an installed continuous improvement culture based on program systematic evaluations.

DATA GATHERING METHODS

In 2021, we carried out the optional standards self-assessment process for our 5 engineering programs. Data gathering was carried out using 2 strategies. The first strategy extracted relevant information from the programs' self-assessment reports for international accreditation under the Washington Accord. This strategy considers the coherence between the accreditation criteria and CDIO Syllabus skills as shown in Table 1, adapted from one presented in Muñoz *et al*. (2020), which was based on Lunev *et al*. (2013). The second mechanism was related to a survey given to the program heads and program committee members, given their in-depth knowledge of their respective programs.

Table 1. Coherence between national and international accreditation criteria and CDIO Syllabus skills (1/2)

Latin-America	Europe	Russia	Generic competencies in Latin-American, European and Russian surveys	ABET	CNA	WA graduate's attributes	CDIO syllabus
LA1	E19	R1	Ability for abstract thinking, analysis, and synthesis	x	X	WA1	2.3
LA17	E14	R2	Ability to work in a team	x	X	WA9	3.1
LA14	E7	R3	Capacity to generate new ideas (creativity)		X		2.4.3/4.2.2/4.2.6/ 4.2.7/4.3.1
LA15	E10	R4	Ability to identify, pose, and resolve problems	x	X	WA2 WA3	2.1.4/2.1.5
LA25	E22	R5	Ability to design and manage projects	x	X	WA3 WA11	4.4/4.5.6/4.6.1
LA2	E11	R6	Ability to apply knowledge in practical situations	x	X	WA1	2.1
LA7	E1	R7	Ability to communicate in a second language	x	X	WA10	3.3
LA8	E27	R8	Skills in the use of information and communications technologies	x	X	WA5	3.2.4
LA10	E2	R9	Capacity to learn and stay up-to-date with learning	x	X	WA12	2.4.6
LA6	E3	R10	Ability to communicate both orally and in the written form in the native language	x	X	WA10	3.2.3/3.2.6/3.2.7
LA24	E26	R11	Ability to work autonomously	x	X	WA9	2.4.1
LA16	E12	R12	Ability to make reasoned decisions	x	X	WA6	2.1
LA22	E25	R14	Appreciation of and respect for diversity and multiculturalism	x	X		2.5.2/2.5.6
LA5/LA21	E23	R15	Ability to act with social responsibility and civic awareness	x	X	WA6	2.4.1/2.4.2/2.5.1/ 2.5.2
LA26	E17	R16	Ability to act based on ethical reasoning	x	X	WA8	2.5
LA20	E28	R17	Commitment to the conservation of the environment	x	X	WA7	4.1.1./4.1.2/4.1.7/ 4.5.6/4.6.1/4.6.6
LA6	E18	R18	Ability to communicate with non-experts about one's field	x	X	WA9 WA10	3.2.1/3.2.7/3.2.8/ 3.2.9/3.2.10
LA3	E5	R19	Ability to plan and manage time	x	X	WA11	2.4
LA27	E30	R20	Ability to evaluate and maintain the quality of work produced	x		WA2	4.4.6/4.5.1/4.5.6/ 4.6.4/4.6.6
LA12	E4	R21	Ability to be critical and self-critical	x	X	WA2	2.4.4
LA11	E8	R22	Ability to search for, process, and analyse information from a variety of sources	x	X	WA4	2.2.2

Table 1. Coherence between national and international accreditation criteria and CDIO Syllabus skills (2/2)

Latin-America	Europe	Russia	Generic competencies in Latin-American, European and Russian surveys	ABET	CNA	WA graduate's attributes	CDIO syllabus
LA20/LA26	E24	R23	Commitment to safety	x	X		2.5.1/4.1
LA18	E21	R24	Interpersonal and interaction skills	x	X	WA9	3.2
LA9	E13	R25	Ability to undertake research at an appropriate level	x	x	WA4	2.2
LA4	E15	R26	Knowledge and understanding of the subject area and understanding of the profession	x	x	WA1	1
LA27	E30	R28	Ability to focus on quality			WA2 WA3 WA6	4.4.6/4.5.1/4.6.4/ 4.6.6
			Generic competencies only in the Russian survey				
LA12		R13	Ability for critical thinking		x	WA2	2.4
		R27	Ability to resolve conflicts and negotiate			WA9	3.2.7/3.2.8
		R29	Ability to focus on results				4.3.1/4.3.2/4.3.3/ 4.3.4
		R30	Ability to innovate		x		2.4.2/2.4.3/2.4.6
			Generic competencies only in the European survey				
LA13	E29		Ability to adapt to and act in new situations		x		2.4.2
LA19	E31		Ability to motivate people and move towards common goals			WA9	
LA23	E16		Ability to work in an international context		x	WA9	3.2.10/3.3.1
	E20		Spirit of enterprise, ability to take initiative		x		2.4.1/4.8
	E6		Ability to show awareness of equal opportunities and gender issues				2.5.5
			Computer Science competencies in the LA survey				
LA13	E12		Ability to adapt to technological changes		x	WA5	2.4.2/4.2.6

RESULTS

The results obtained after gathering and processing information are shown in Figure 4. Among the main findings, the Electrical Engineering and Civil Engineering programs have the highest achievement level for the Sustainable development standard. In the case of the first program, this is explained because this competence is part of the graduate attribute profile. Likewise, the nature of the Civil Engineering discipline explains its high achievement level. Simulation-based mathematics (optional standard 2) is present in all programs in at least 1 course (level 2), reaching level 4 in the Electrical Engineering and Geological Engineering programs. Entrepreneurship (optional standard 3) is being addressed at the institutional level by the CreoeInnovo UCSC program, an initiative that aims to strengthen and promote the development of innovation and entrepreneurship skills for all students at UCSC. A slightly more recent UCSC Internationalization initiative, launched in 2020, explains Internationalization (optional standard 4) reaching level 2 in almost all programs. This latest

initiative allows students to take courses at any institution belonging to the G9[12] Network through the Virtual Student Mobility project. The G9 Network brings together nine non-state public universities of the Rector's Council. Thanks to this mobility project, any student will be able to study online a subject from another institution associated with the G9 during the first semester of 2022.

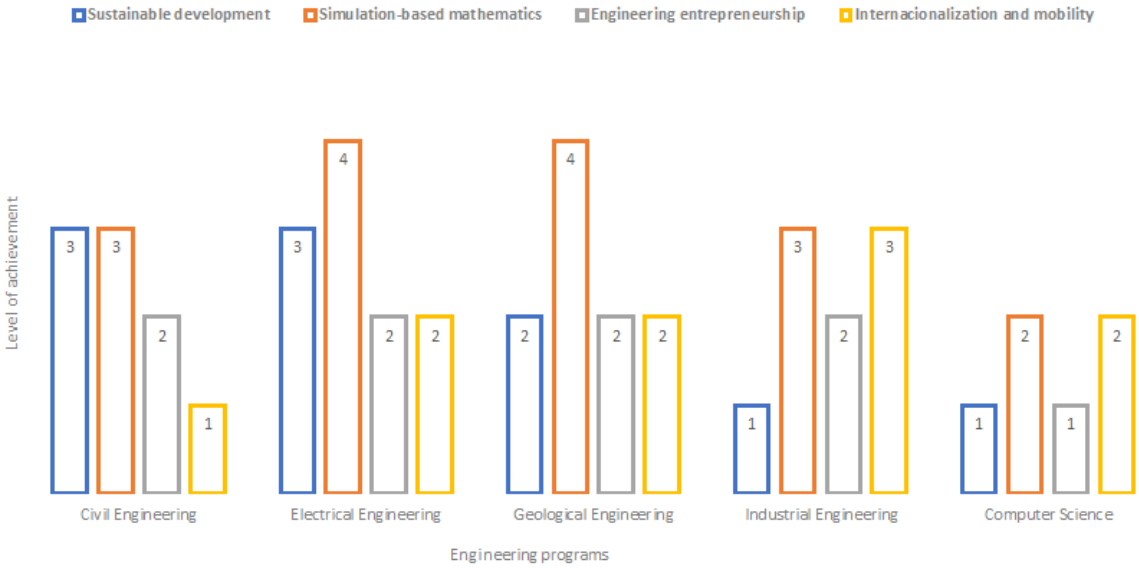

Figure 4. Optional standards achievement levels at the School of Engineering.

DISCUSSION AND PROPOSALS

We recognize that adopting the CDIO Initiative in 2011 has installed a culture of continuous improvement of our engineering programs that gives us a strong foundation for an international accreditation process. As a result, we have improved and systematized our data gathering processes.

Regarding the optional CDIO standards, our programs have not reached uniform achievement levels, being Computer Science the program with the lowest levels. However, all programs present standards at levels 2 or lower, as seen in Figure 4. It is recommended to focus our efforts on ensuring that all programs achieve at least level 3 in all four optional standards. This work should start by March 2022, to attain level 3 by the end of 2026. It is recommended to incorporate the proposed actions into the current improvement plans to ensure financing. If this is not possible, these standards should be made explicit in the actions currently planned for the coming years. It is recommended to leave the plans for standards 3 and 4 in institutional hands, actively participating in the actions and initiatives available to achieve progress. Table 2 presents some actions from our improvement plan, common to all engineering programs for the 2022-2024 period

[1] https://internacionalizacion.ucsc.cl/

[2] The G9 Network of Non-State Public Universities brings together universities belonging to the Chilean Universities Rector's Council (CRUCh). Eight of them are regional universities, from the north, center and south of the country. These institutions have a long tradition and history of proven public service. The G9 institutions are committed to Chile and its development, are diverse and inclusive and are national and international benchmarks in various matters, leading the agenda for regional development.

Table 2. Improvement plan 2022-2024 (elements common to all engineering programs).

Action	Goal	Period	Responsible	Linked to institutional strategic plan or program improvement plan
Foster sustainable development aspects in real-world projects developed during the program (optional standard 1)	At least 2 experiences per program incorporating sustainable development (one at a basic level and one an advanced level, leveraging current design-implement experiences)	From 2022 to the end of accreditation period	Program head / Faculty	Yes
Foster enrollment in entrepreneurship courses (optional standard 3)	At least 10% of all program students	Starting 2022	Program head	No
Active participation in the UCSC internationalization program linked to the USC 20102 project (optional standard 4)	At least 1 international student experience per year	Starting 2022	Department head and Institutional Relations Director	Yes

Additionally, in 2020, UCSC declared its commitment to the Sustainable Development Goals and stated a model that contributes to these goals through its teaching, research, development, innovation, entrepreneurship, cooperation, and outreach, thus assuring that UCSC has a commitment to supporting initiatives in that direction.

CONCLUSIONS

Adopting the CDIO Initiative in 2011 has proven to be a strong strategy for installing a culture of continuous improvement in the School of Engineering. Both the 12 Core Standards and the 4 Optional Standards have been helpful guidelines to prepare our programs for an international accreditation process.

Our optional standards self-assessment process has reinforced our commitment to work to achieve at least level 3 in all our engineering programs, especially in the Computer Science and Industrial Engineering programs. To that extent, our improvement plans propose that all programs include an annual interdisciplinary design-implement experience focusing on sustainability, electromobility, climate change, among others.

Starting the first semester of 2022, the institutional internationalization plan will allow us to address optional standard 4, either through the G9 Virtual Student Mobility project or by teaching courses in a second language.

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BIOGRAPHICAL INFORMATION

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