A TOOL FOR CDIO STANDARDS COMPLIANCE LEVELS MONITORING

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ABSTRACT

This article presents a tool for monitoring the compliance level with the CDIO standards of engineering programs. This tool is currently in use at the School of Engineering of the Universidad Católica de la Santísima Concepción (UCSC), Chile to monitor five engineering programs. Since 2011, the School of Engineering at UCSC has been implementing a curricular reform based on the CDIO approach. In 2013, a preliminary self-evaluation of the adoption of the CDIO Initiative standards in these programs was done, and its results showed an overall compliance level of 3 for most standards, higher compliance levels for standards 2 and 4, and lower compliance levels for standard 9. This preliminary self-evaluation motivated us to design a tool to aid the process of systematically gathering the data needed to monitor CDIO standards compliance levels periodically across all programs. This monitoring tool allows us to associate measurements and metrics relating to several relevant factors to each CDIO standard. Thus, by using quantitative evidence gathered for these measurements and metrics, the tool aids the process of evaluating the compliance level for each standard. All relevant compliance information is presented in an easy-to-understand radial graph. The tool can also display the evolution of CDIO compliance levels for each program across different periods. Program managers and administrators can then use this tool to detect strengths and weaknesses in a timely manner, and to make informed and prompt decisions aimed at achieving high compliance levels for each standard. The tool is easy to configure and very flexible: while it provides a basic set of measurements and metrics, they can be added and removed at will to tailor the tool to the each program's specific needs of each program. The number of programs to monitor is also configurable, so administrators can add or remove programs at will.

KEYWORDS

Program Evaluation, Self-Evaluation, Standards: 12

FRAMEWORK

In 2011, the UCSC School of Engineering reformed the curricula of its five engineering programs (Loyer et al., 2011) based on the CDIO initiative (Crawley et al., 2007). Among other issues, the curriculum reform process at UCSC incorporates first-year courses to address the problem of motivating its first years' students (Muñoz et al., 2013). In these courses, students participate in active learning activities to familiarize themselves with their professional role, communicational skills and teamwork, thus contributing to the adoption of CDIO standards 1, 4 and 8.

In 2013, we performed a preliminary self-evaluation of the adoption of the CDIO standards in these programs. Its results showed that, while most standards had an overall compliance level of 3, standards 2, and 4 had higher compliance levels, and standard 9 had a compliance level of 1 (Martínez et al., 2013). This preliminary self-evaluation motivated us to design a tool to aid the process of systematically gathering the data needed to monitor CDIO standards compliance levels periodically across all programs.

PROGRAM EVALUATION

Evaluation of CDIO programs primarily follows a standards-based model (Brodeur, D. & Crawley, E., 2005), focusing on inputs, processes and outputs. In this model, inputs include feedback from all stakeholders, the use and usability of facilities, and the use and availability of resources (addressed by standards 1 and 6). Processes include teaching, assessment and evaluation methods (addressed by standards 3, 4, 5, 7, 8, 9, 10 and 11). Outputs are the intended learning outcomes for students and the overall impact of a program (addressed by standards 2 and 11). Finally, it is important to mention that standard 12 is the criterion for the program evaluation itself (Crawley, E. et al., 2007).

THE CDIO MODEL AND CHILEAN PROGRAM ACCREDITATION

The Chilean accreditation system considers the institutional accreditation of higher education institutions, undergraduate programs and graduate programs. According to Chilean law No. 20.129 (CNA, 2009), the *Comisión Nacional de Acreditación (CNA)* is responsible for granting accreditation status to higher education institutions. In the case of undergraduate programs, accreditation agencies, authorized by the CNA, certify the quality assurance of those programs that voluntarily undergo the accreditation process. However, undergraduate programs granting degrees in Medicine and Education must mandatorily undergo the accreditation process.

It can be noted that the CDIO standards-based model is consistent with the Chilean accreditation model, which is based on a set of criteria, requires evidences of compliance with the criteria and program improvement plans. Table 1 shows the coherence among the CDIO syllabus (Crawley et al., 2011), CNA competences and UCSC generic competences. Likewise, table 2 shows how CNA engineering evaluation criteria relate to CDIO standards.

Table 1. Coherence between CDIO Syllabus, CNA and UCSC Competences

CDIO Levels	CDIO Syllabus	CAN & UCSC Competences
1	DISCIPLINARY KNOWLEDGE AND REASONING	
1.1	Knowledge of underlying mathematics and sciences	x
1.2	Core engineering fundamental knowledge	x
1.3	Advanced engineering fundamental knowledge, methods and tools	x
2	PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	
2.1	Analytical reasoning and problem solving	x
2.2	Experimentation, investigation and knowledge discovery	x
2.2.2	Survey of Print and Electronic Literature	x
2.3	System thinking	x
2.4.1	Initiative and the Willingness to Make Decisions in the Face of Uncertainty	x
2.4.2	Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility	x
2.4.2.6	Adaptation to change	x
2.4.3	Creative Thinking	x
2.4.4	Critical Thinking	x
2.4.5	Self-awareness, Metacognition and Knowledge Integration	x
2.4.6	Lifelong Learning and Educating	x
2.4.7	Time and Resource Management	x
2.5.1	Ethics, Integrity and Social Responsibility	x
2.5.2	Professional Behavior	x
2.5.4	Staying Current on the World of Engineering	x
2.5.5.1	A commitment to treat others with equity	x
2.5.5.2	Embracing diversity in groups and workforce	x
2.5.6	Trust and loyalty	x
3	INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	
3.1	Teamwork	x
3.2	Communications	x
3.2.4	Electronic/Multimedia Communication.	x
3.3.1	Communications in English.	x
4	CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS	
4.1	External, societal, and environmental context	x
4.2	Enterprise and business context	x
4.3	Conceiving, systems engineering and management	x
4.4	Designing	x
4.5	Implementing	x
4.6	Operating	x
4.7	Leading engineering endeavors	x
4.8	Entrepreneurship	x

Table 2. Relation between CNA Engineering Evaluation Criteria and CDIO standards

CNA ENGINEERING EVALUATION CRITERIA	CDIO STANDARDS
PROGRAM GOALS AND RESULTS	
Curricular structure	1, 2, 3, 4, 5, 11,12
Teaching and learning process	5, 7, 8, 11
Learning outcomes	2, 11,12
Enterprise and community relations	1, 3, 4, 5, 7, 8, 9
OPERATIONAL REQUIREMENTS	
Humans resources	9, 10
Infrastructure	6
SELF-REGULATION CAPACITY	
Program objectives	1, 2, 3, 4, 12
Self-evaluation	11, 12

CONTINUOUS PROGRAM IMPROVEMENT MODEL

Our continuous program improvement model considers several stages to promote quality assurance, as shown in Figure 1. The diagnostic stage examines the compliance of accreditation criteria associated to program goals and results, operational requirements and self-regulation capacity. The planning stage includes a strategic plan and a program improvement plan, which are not necessarily done at the same time. The global evaluation stage monitors the program implementation at three specific moments: it assesses the students' entry-level competencies, faculty competencies and learning spaces at the beginning of the semester, then it evaluates the formation process at the end of the semester and finally it assesses the students' learning outcomes at the end of the academic year. The impact evaluation stage provides evidences of a program's overall success in meeting its goals and its impact on the respective stakeholders such as industry and the community. The last two stages provide data and information for continuous program improvement. More details about the instruments, evaluation reports, stakeholders and CDIO standards involved are presented in table 3.

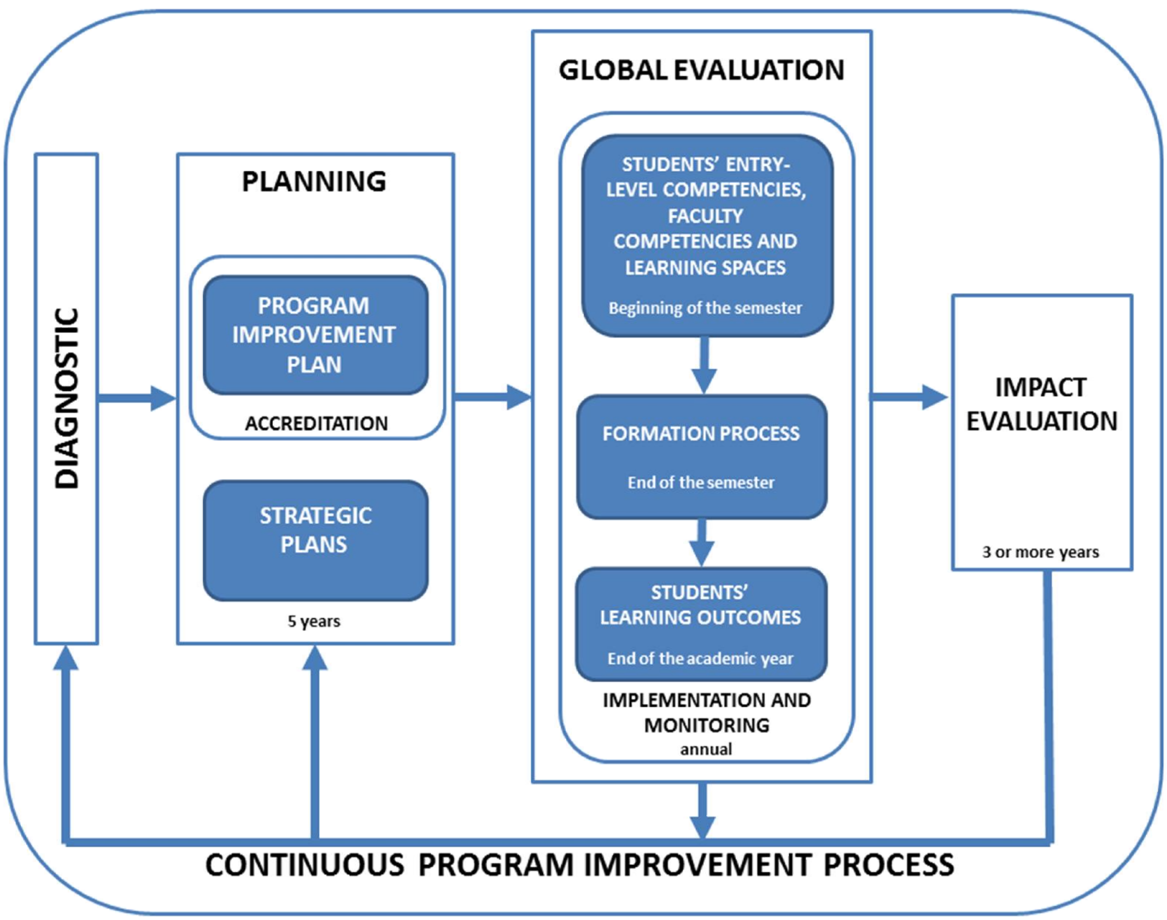


Figure 1. Continuous program improvement model of the UCSC School of Engineering

Table 3. Instruments, evaluation reports and stakeholders for the evaluation program

	Diagnostic	Planning (5 years)		Global evaluation (annual)							Impact evaluation (3 or more years)	
	Self-evaluation report (Standards : 1 to 12)	Improvement plan (Standards : 1 to 12)	Strategic plans (Standards: 1 to 12)	Students' entry-level competencies, operational conditions report (Standard s: 2, 6, 9, 10)	UCSC Mentoring Program (Standard s: 2, 8, 11)	Course catalogue and class scheduling report (Standard: 2)	Curricular progress and students retention report (Standard: 11)	Student's survey and teaching competencies report (Standard: 10)	Faculty development report (Standards: 9, 10)	Stakeholders surveys (Standard: 12)	CDIO standards compliance report (Standards : 1 to12)	Long-term impact report (Standard: 12)
School of Engineering	x	x	x	x	x	X	x	x	x	x	x	x
Faculty	x	x	x	x	x	X			x	x	x	x
Students	x		x	x	x		x	x		x	x	x
Admission and Registrar's Office		x	x	x			x				x	
Office of Academic Affairs			x	x		X	x	x			x	
Office of Strategic Development	x	x	x						x	x	x	x
Office of Students Affairs			x	x	x	X					x	
Office of Community Relations	x		x						x	x	x	x
Teaching and Learning Center		x	x						x		x	
CNA	x	x								x	x	
Alumni	x	x	x							x	x	x
Employers	x	x	x							x	x	x

A CDIO STANDARDS COMPLIANCE LEVEL MONITORING TOOL

As mentioned before, our continuous program improvement model requires monitoring and evaluating CDIO standards compliance level (CDIO, 2010a), compliance with Chilean accreditation criteria, as well as the progress of the strategic plans at the institutional, school and departmental levels. To help this process, we developed a monitoring tool to visualize evidences, indicators and compliance levels, which can be used by any program director, department head and/or other authorities.

It is worth noting that, given the broad evaluation focus, we had to place results-oriented indicators on one side and process-oriented evidence on the other side. The indicators were gathered and consolidated from the above mentioned strategic and improvement plans related to the School of Engineering's program accreditation processes, and those indicators agreed upon in MECESUP project USC1308 of the Chilean Ministry of Education, whose goal is to contribute to CDIO standards compliance in the UCSC School of Engineering programs.

Tool structure

The monitoring tool's components are shown in Figure 2. The following paragraphs describe each component in detail.

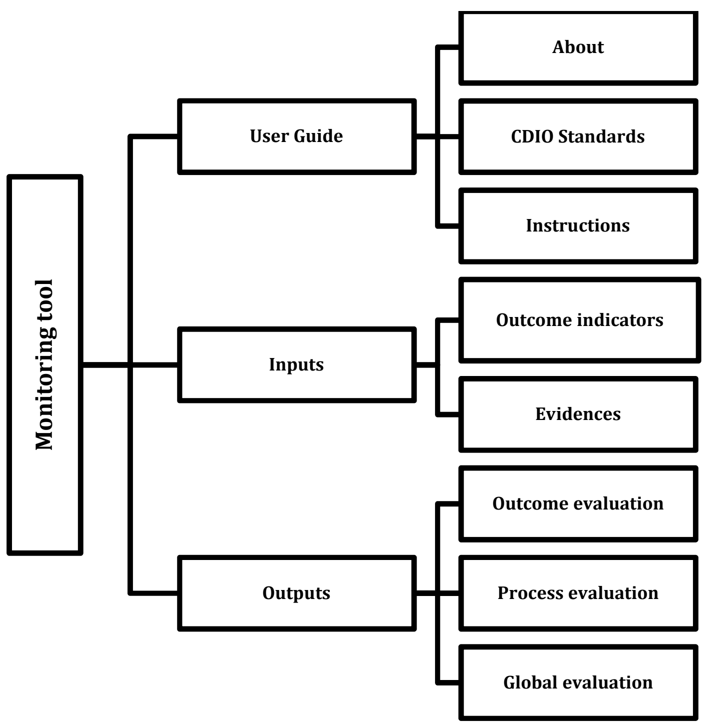


Figure 2. Monitoring tool structure

User guide: It includes the monitoring tool goals, user profile descriptions, explanations for the 12 CDIO standards and usage instructions.

Inputs: the tool receives two kinds of input data. First, it receives *a list of indicators* associated with each CDIO standard, including their definitions, formulae, i^{th}-year baseline, current value, jth-year goal, along with other parameters whose minimum and maximum values are given by the strategic and improvement plans. Initially, it includes about 30 basic indicators in all program evaluation areas. Second, it receives *a list of process-oriented evidence*, including the relevant standard, evidence description and standard compliance level given in a 0-5 range (CDIO, 2010b). The Input module can be used to personalize an indicator by modifying its baseline and/or goals, as well as to add or remove an indicator or evidence from the corresponding list.

Outputs: The tool generates three kinds of evaluations. The *outcome evaluation* is shown via an indicator table which uses a traffic light to visualize an indicator's compliance level with regards to its actual value and the goal set by a strategic or improvement plan for a given program. Figure 3 shows a fragment of the indicator table for the Industrial Engineering program. The *process evaluation* is shown via a CDIO standards compliance level table and a radial graph. The table visualizes compliance levels as high (levels 4 and 5), intermediate (level 3) or low (levels 0 to 2), as shown in Figure 4. The radial graph summarizes compliance levels for each program, as shown in Figure 5. Finally, the *global evaluation* uses a radial graph to visualize all School of Engineering programs compliance levels, as shown in Figure 6.

MONITORING PROGRAM

Outcome indicators of Industrial Engineering Program at UCSC

Indicators	Industrial Engineering
Nationally accredited program (years)	5
Internationally accredited program (years)	0
Employment rate (1st. year)	89
Math courses passing rate	60
Retention rate (1st. year)	89
Retention rate (3rd. year)	72

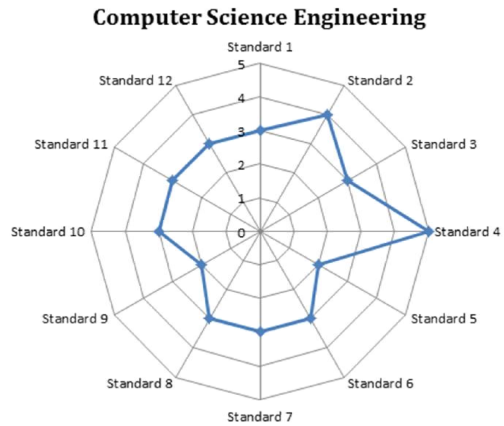
Figure 3. Outcome evaluation table

MONITORING PROGRAM

CDIO standards achievement levels of the School of Engineering Programs

CDIO	Computer Science Engineering	Industrial Engineering	Geological Engineering	Civil Engineering	Electrical Engineering
Standard 1	3	3	1	3	3
Standard 2	4	4	4	4	3
Standard 3	3	3	3	3	2
Standard 4	5	5	3	5	2
Standard 5	2	3	1	2	2
Standard 6	3	3	3	3	2
Standard 7	3	3	2	3	2
Standard 8	3	3	3	2	2
Standard 9	2	2	3	3	2
Standard 10	3	3	3	3	2
Standard 11	3	3	2	3	2
Standard 12	3	3	2	3	2

Figure 4. Process evaluation table



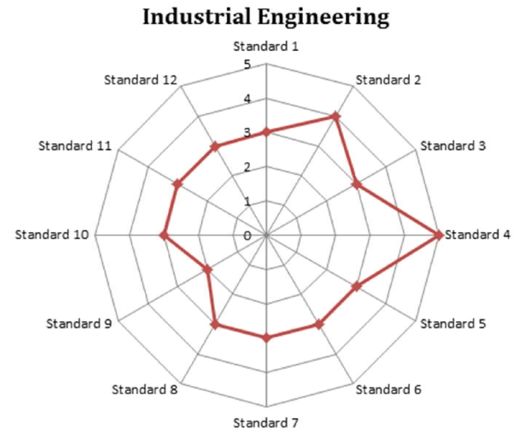


Figure 5. Process evaluation graph

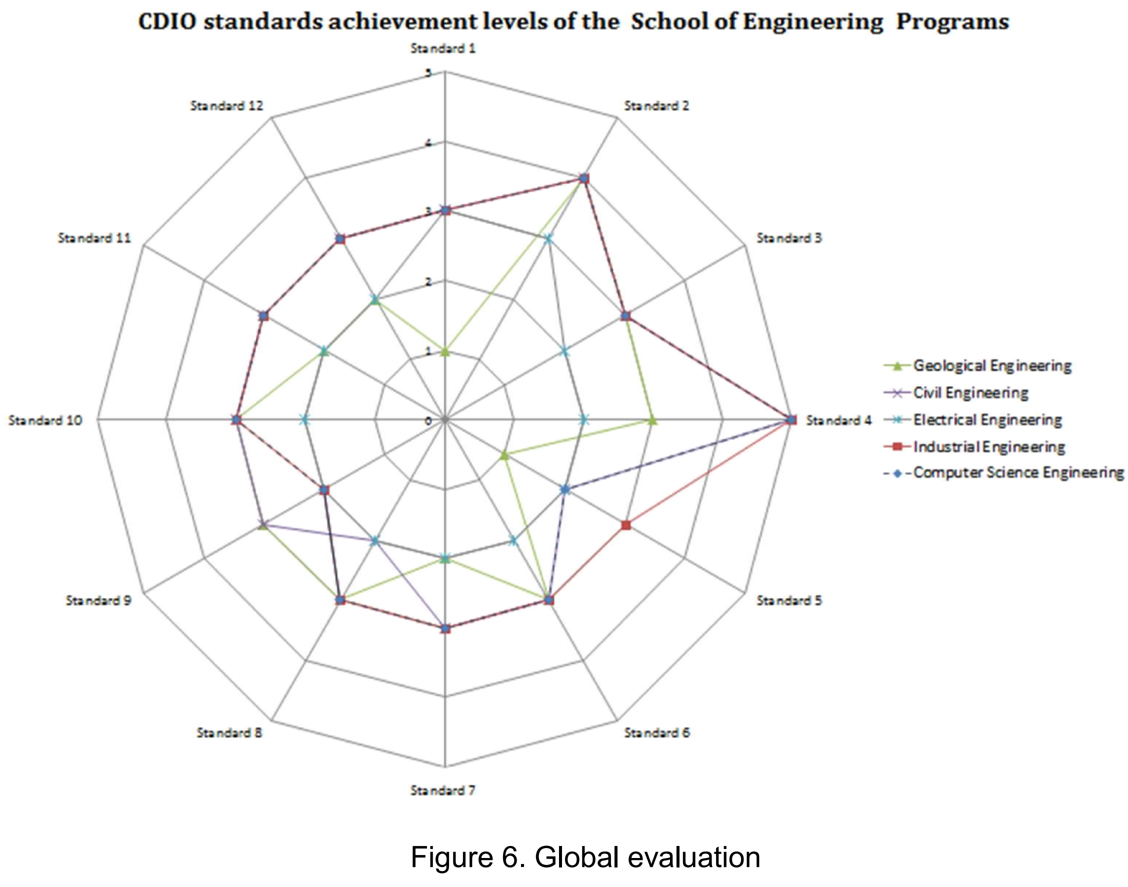


Figure 6. Global evaluation

DISCUSSION AND FUTURE WORK

Currently, the monitoring tool is used to support the continuous program improvement model of the UCSC School of Engineering, whose main goal is to evaluate CDIO standards compliance for its programs that follow the CDIO model. However, thanks to its flexibility and versatility, it can also be applied to any program evaluation model at the basic indicator level. To broaden its appeal and increase its usefulness, it would be desirable to be able to interface with those transactional database systems commonly used in institutions of higher education, thus allowing access to indicators and data, which in turn can be used to calculate new relevant indicators for program management. At the same time, it would be useful to collect and manage historical reports for different programs so as to compare results and evaluate the impact of continuous improvement actions.

CONCLUSIONS

The monitoring tool described contributes to the tracking of the implementation of the curricular reform process of the UCSC School of Engineering programs and to CDIO standards compliance level evaluation. At the same time, the monitoring tool aids curriculum management by visualizing results and validated evidence for decision making regarding program goals, strategic plans, and improvement plans agreed upon in previous accreditation process. Finally, the tool's flexibility and versatility allows program directors to configure and incorporate new specific indicators and evidence to tailor the tool for their specific programs.

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BIOGRAPHICAL INFORMATION

Claudia Martínez studied Computer Science at the University of Concepción, and obtained her Master in Educational Informatics at the Universidad de la Frontera. Currently she is a faculty member in the Computer Science department at the Universidad Católica de la Santísima Concepción, where she also serves as the department head. Her research and interest area are related with Information retrieval and Semantic web.

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