CDIO STANDARDS COMPLIANCE: MONITORING PERCEPTION OF STUDENTS' PROFICIENCY LEVELS

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ABSTRACT

This article presents a mechanism for monitoring a program's effectiveness in reaching its intended educational goals across the curriculum. Starting in 2011, the School of Engineering at UCSC has been implementing a CDIO-based curricular reform. Since then, we have performed a biennial self-evaluation of the Computer Science program's compliance with the CDIO standards. Along the way, we have developed tools and mechanisms to systematize data gathering for these continuous evaluation processes. In particular, we have defined three intermediate milestones at which to measure the achievement of student learning outcomes associated with CDIO Syllabus levels 2, 3 and 4, at the end of the second, sixth and ninth semesters. At each milestone, we are interested not only in analyzing data associated with traditional course-level grades, but also in how student achievement levels are perceived by students and instructors. Then, we measure the gaps between these perceptions and present them in easy-to-understand radial graphs. This information is used to detect low proficiency levels and to manage instructors and students expectations of their proficiency levels at each milestone. Also, students must have done a summer internship by the end of the ninth semester. Students must fill a self-evaluation performance survey regarding their internship, while employers must evaluate the student's performance. These surveys focus on personal and interpersonal skills and attitudes. Again, we measure the gaps between these results. This mechanism has been applied every semester since 2015. Our preliminary results have shown that student and instructor perception of proficiency levels show a larger variance for the first two milestones. However, by the end of the ninth semester, these gaps have been reduced, which shows that both students and instructors have a better understanding of their proficiency levels. Moreover, students are slightly more critical of their competence levels than their instructors and employers.

KEYWORDS

Program evaluation, Standards compliance, Syllabus proficiency levels, Standards: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

From 2008 to 2010, the School of Engineering at the Universidad Católica de la Santísima Concepción (UCSC) underwent a curricular reform based on the CDIO approach (Crawley et al., 2007). This process was driven by the results of accreditation self-evaluation processes and guided by the best practices given by the CDIO Initiative, in particular the CDIO Syllabus and its 12 standards. In 2011, the UCSC School of Engineering began implementing the new curricula in its five engineering programs (Loyer et al., 2011). A central aspect of our institutional pedagogical model and of this new curriculum is the promotion of active learning (Muñoz et al., 2013; Cárdenas et al., 2013; Loyer, 2013; Cea et al., 2014; Martínez & Muñoz, 2014; Martínez & Cárdenas, 2014; Cea et al., 2015) which involves the implementation of faculty enhancement plans, new workspaces, and the implementation of program monitoring and evaluation mechanisms. These improvements were supported by the Chilean Ministry of Education MECESUP program, through grants MECESUP USC 0610, FIAC USC 1101 and PM USC 1308.

FRAMEWORK

CDIO Initiative

The CDIO Syllabus details the set of skills a graduating engineer is expected to acquire to a given degree of proficiency at the end of his studies. It classifies learning outcomes into four high-level categories: technical knowledge, personal and professional attributes, interpersonal skills and the skills specific to the engineering profession. Each category is refined to four levels of detail (Crawley, 2001). The CDIO Syllabus was revised and updated to add missing skills such as Leadership and Entrepreneurship, and to clarify nomenclature in (Crawley et al., 2011).

The CDIO standards comprise 12 guiding principles that aid curriculum design and foster continuous program improvement. These standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-implement experiences and workspaces (Standards 5 and 6), methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12). Each standard is presented in (Brodeur & Crawley, 2005; CDIO, 2010) with a description, a rationale and a rubric.

Regarding CDIO Standards compliance, our continuous program improvement model establishes biennial standards adoption reviews for our study programs. Figure 1 shows preliminary review results for the Computer Science program for years 2013 and 2015 (Martínez et al., 2013; Martínez et al., 2015). It can be seen that, in general, compliance levels for most standards are at level 3 (“Implementation of the plan to address the standard is underway across the program components and constituents”), except for standard 4 which reaches compliance level 5 (“The introductory course is regularly evaluated and revised, based on feedback from students, instructors and other stakeholders”). It must be noted that engineering programs in Chile usually are formally 6-year programs, but many students take longer to graduate. In particular, our new Computer Science program has not graduated any students yet. Therefore, the results shown in this work are preliminary.

Learning objectives evaluation model

Our learning objectives evaluation model focuses both on evaluating the coursework learning outcomes and on monitoring student progress in accomplishing the program’s learning objectives, as shown in Figure 2. At a micro level, it evaluates the achievement of each course’s learning outcome; at a macro level, it monitors the achievement of the program’s learning objectives at different program milestones: at the end of the second, sixth and ninth semesters (Cárdenas et al., 2012).

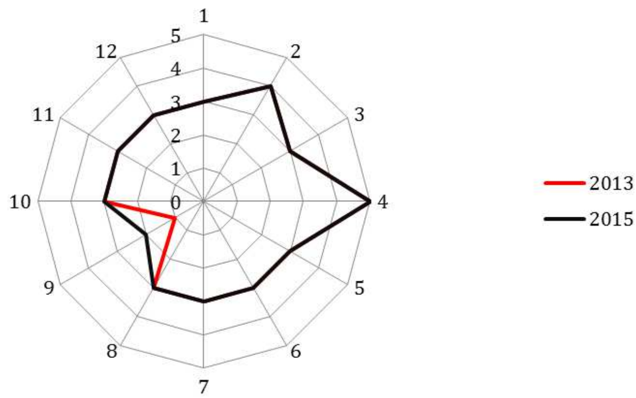


Figure 1. CDIO standards self-evaluation results

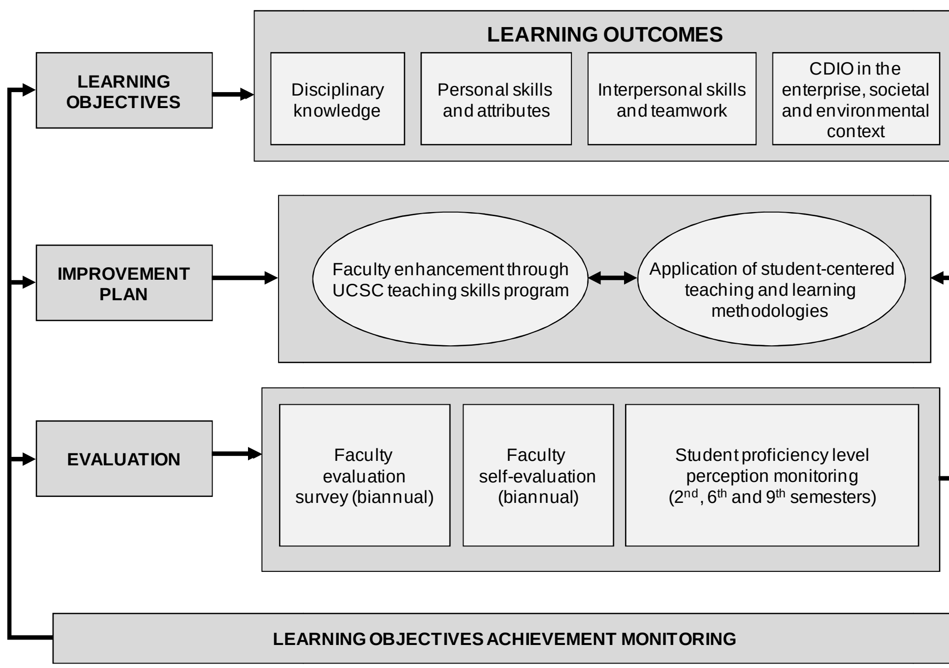


Figure 2. Learning objectives evaluation model

STUDENTS' PROFICIENCY LEVELS FOR THE CDIO SYLLABUS

In order to guarantee the achievement of the program learning objectives, the curricular design process generated a mapping for all compulsory courses of the Computer Science program to the CDIO Syllabus skills, which, for each course, indicated whether a given relevant skill was introduced, taught or used in that course. Then, each course's learning outcomes were defined. Later, as part of our continuous improvement process, we defined expected proficiency levels for each mapped skill, using the correspondence of MIT activity-based proficiency and Bloom scales described in Crawley as a guideline (Crawley, 2001, p. 30). These proficiency levels are shown in Table 1.

Table 1. CDIO Syllabus skill proficiency levels

Student proficiency level		Instructor opinion of student proficiency level	
		0	Not observed
1	To have experienced or been exposed to	1	Have been experienced or been exposed to
2	To be able to participate in and contribute to	2	Are able to participate in and contribute to
3	To be able to understand and explain	3	Are able to understand and explain
4	To be skilled in the practice or implementation	4	Are skilled in the practice or implementation
5	To be able to lead or innovate in	5	Are able to lead or innovate in

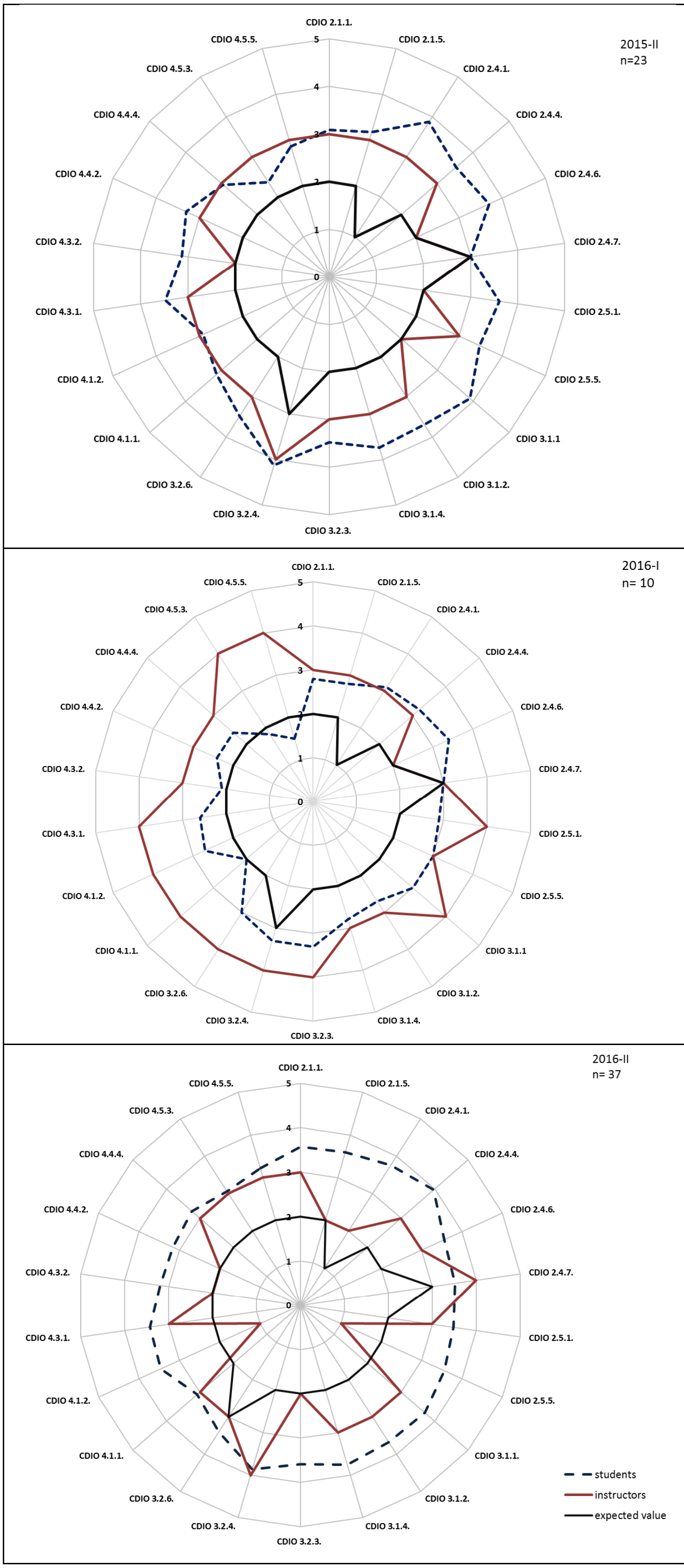
As mentioned before, at a micro level we assess the learning outcomes in each course, and at a macro level we monitor the students' progression at three milestones. In particular, we wish to evaluate the development of three CDIO skills: personal and professional attributes, interpersonal skills and the CDIO skills in a real-world context, up to the third level of detail.

In order to do this, we gather the perception of student achievement levels in both students and instructors by means of surveys similar to the one presented in Appendix H of the CDIO Syllabus (Crawley, 2001) using the proficiency levels shown in Table 1. Then, we measure the gaps between the expected proficiency level and these two perceptions, presenting them in easy-to-understand radial graphs. This information is used to detect low proficiency levels and to manage instructors and students' expectations of their proficiency levels at each milestone. It is worth noting that instructor surveys use a proficiency level of 0 to indicate that the instructor has not observed a particular skill in his students.

RESULTS

For all three milestones, a compulsory Computer Science course was chosen and both the students and its instructor were surveyed. For the first milestone, the Programming Lab I course was surveyed on semesters 2015-II, 2016-I and 2016-II. For the second milestone, the Databases course was surveyed the same three semesters. For the third milestone, the Software Engineering Lab II course was surveyed only the 2016-I semester, as it is taught only once a year. Additionally, students are required to do a summer internship at the end of the 8^{th} semester. Both students and their employers are surveyed at the end of the internship about a reduced set of relevant CDIO skills.

Survey results for each milestone are shown in Figures 3, 4 and 5. Even though students were surveyed about all CDIO skills at the third level of detail, these figures only present the subset deemed relevant at that milestone according to the skill mapping mentioned before. Our preliminary results show that, by the first milestone, student and instructor perception of proficiency levels show a large variance between them and also with the program's expected proficiency level, for all three semesters. In general, students have a higher perception of their achievement levels than theirs instructors and the expected value. The exception is the 2016-I semester, when the course is taken by students that have already failed this course once, and their perception of their proficiency level in general is lower than their instructor´s perception. By the second milestone, students' perception of proficiency levels is closer to the program's expected level. However, instructors' perception are more critical for those CDIO skills that he or she observed during the course (proficiency level greater than 0). However, by the end of the ninth semester, the gaps between the student's and instructors' perceptions have been reduced, which shows that both students and instructors have a better understanding of student proficiency levels. Moreover, students are slightly more critical of their competence levels than their instructors and employers.



2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES

2.1 ANALYTICAL REASONING AND PROBLEM SOLVING

2.1.1 Problem Identification and Formulation
2.1.5 Solution and Recommendation

2.4 ATTITUDES, THOUGHT AND LEARNING

2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty
2.4.4 Critical Thinking
2.4.6 Lifelong Learning and Educating
2.4.7 Time and Resource Management

2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES

2.5.1 Ethics, Integrity and Social Responsibility
2.5.5 Equity and Diversity

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION

3.1 TEAMWORK

3.1.1 Forming Effective Teams
3.1.2 Team Operation
3.1.4 Team Leadership

3.2 COMMUNICATIONS

3.2.3 Written Communication
3.2.4 Electronic/Multimedia Communication
3.2.6 Oral Presentation

4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS

4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT

4.1.1 Roles and Responsibility of Engineers
4.1.2 The Impact of Engineering on Society and the Environment

4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT

4.3.1 Understanding Needs and Setting Goals
4.3.2 Defining Function, Concept and Architecture

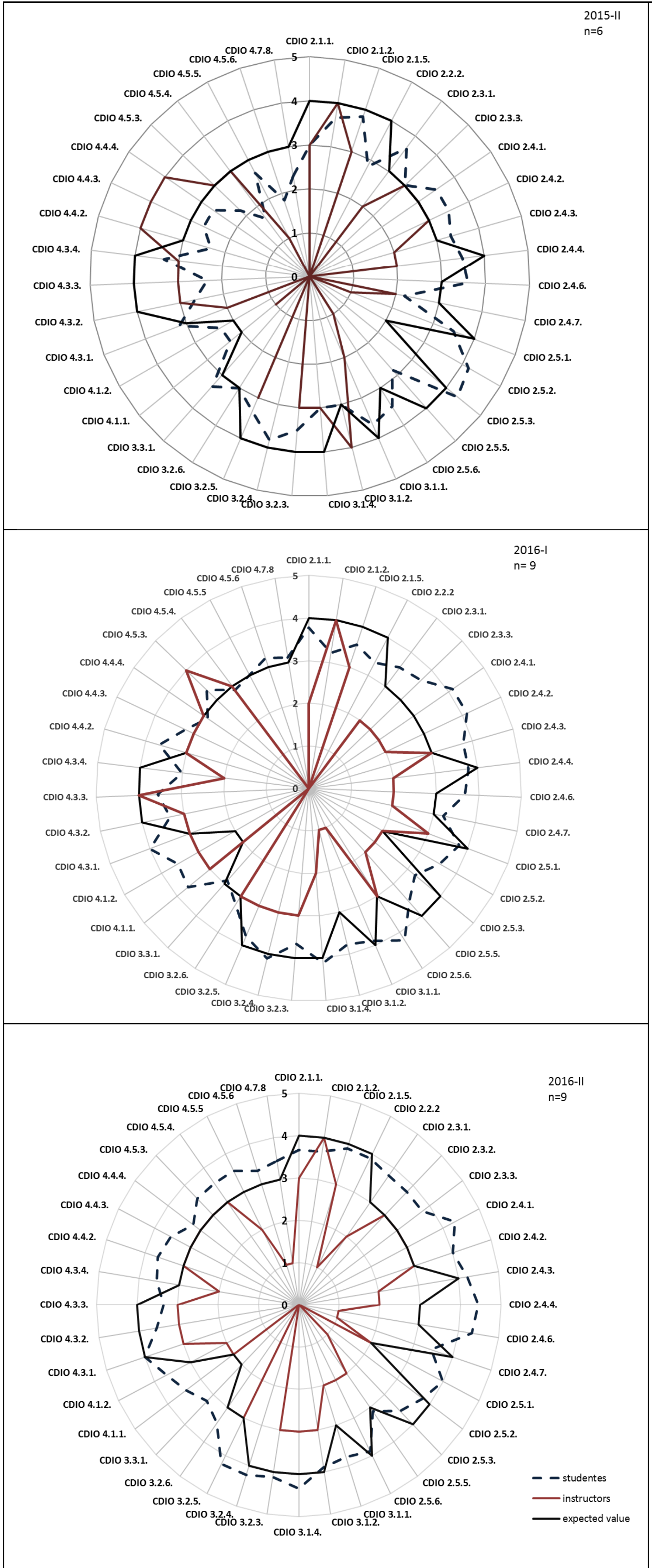
4.4 DESIGNING

4.4.2 The Design Process Phasing and Approaches
4.4.4 Disciplinary Design

4.5 IMPLEMENTING

4.5.3 Software Implementing Process
4.5.5 Test, Verification, Validation, and Certification

Figure 3. First milestone proficiency level perception: Programming Lab I



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- 2.1.1 Problem Identification and Formulation
- 2.1.2 Modeling
- 2.1.5 Solution and Recommendation

2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY
- 2.2.2 Survey of Print and Electronic Literature

2.3 SYSTEM THINKING
- 2.3.1 Thinking Holistically
- 2.3.3 Prioritization and Focus

2.4 ATTITUDES, THOUGHT AND LEARNING
- 2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty
- 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility
- 2.4.3 Creative Thinking
- 2.4.4 Critical Thinking
- 2.4.6 Lifelong Learning and Educating
- 2.4.7 Time and Resource Management

2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES
- 2.5.1 Ethics, Integrity and Social Responsibility
- 2.5.2 Professional Behavior
- 2.5.3 Proactive Vision and Intention in Life
- 2.5.5 Equity and Diversity

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- 3.2.5 Graphical Communication
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3.3 COMMUNICATIONS IN FOREIGN LANGUAGES
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- 4.3.2 Defining Function, Concept and Architecture
- 4.3.3 System Engineering, Modeling and Interfaces
- 4.3.4 Development Project Management

4.4 DESIGNING
- 4.4.2 The Design Process Phasing and Approaches
- 4.4.3 Utilization of Knowledge in Design
- 4.4.4 Disciplinary Design

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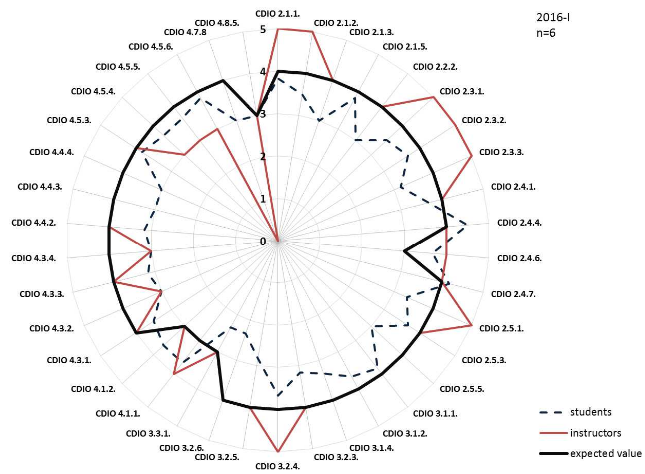
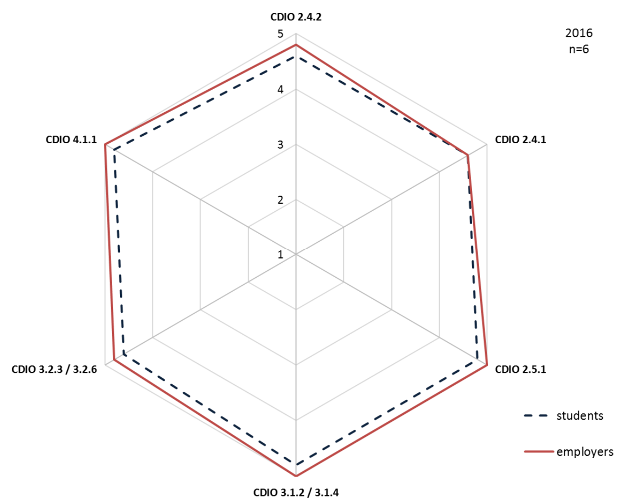
- 4.5.2 Hardware Manufacturing Process
- 4.5.3 Software Implementing Process
- 4.5.4 Hardware Software Integration
- 4.5.5 Test, Verification, Validation, and Certification
- 4.5.6 Implementation Management

4.7 LEADING ENGINEERING ENDEAVORS
- 4.7.8 Innovation – the Conception, Design and Introduction of New Goods and Services

Figure 4. Second milestone proficiency level perception: Databases



Internships



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- 2.1.2 Modeling
- 2.1.3 Estimation and Qualitative Analysis
- 2.1.5 Solution and Recommendation

2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY

- 2.2.2 Survey of Print and Electronic Literature

2.3 SYSTEM THINKING

- 2.3.1 Thinking Holistically
- 2.3.2 Emergence and Interactions in Systems
- 2.3.3 Prioritization and Focus

2.4 ATTITUDES, THOUGHT AND LEARNING

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- 4.5.6 Implementation Management

4.7 LEADING ENGINEERING ENDEAVORS

- 4.7.8 Innovation – the Conception, Design and Introduction of New Goods and Services

4.8 ENTREPRENEURSHIP

- 4.8.5 Conceiving Products and Services around New Technologies

Figure 5. Third milestone proficiency level perception: Software Engineering Lab II and internships

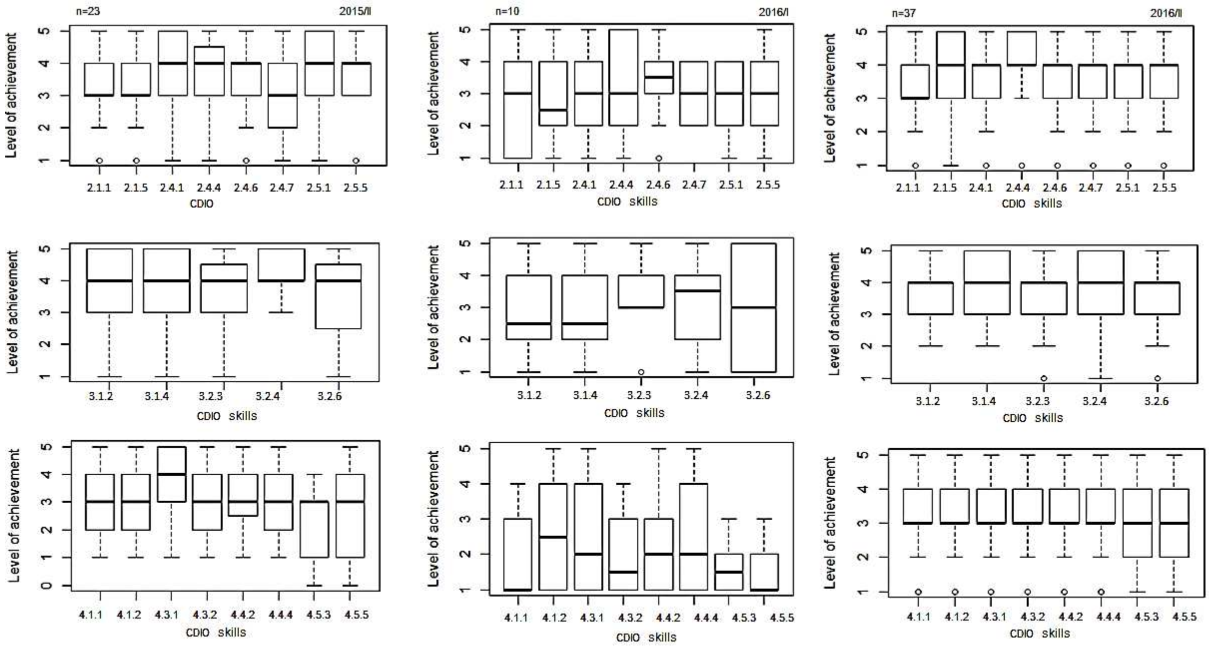

Figure 6. First milestone proficiency level perception data distribution: Programming Lab I

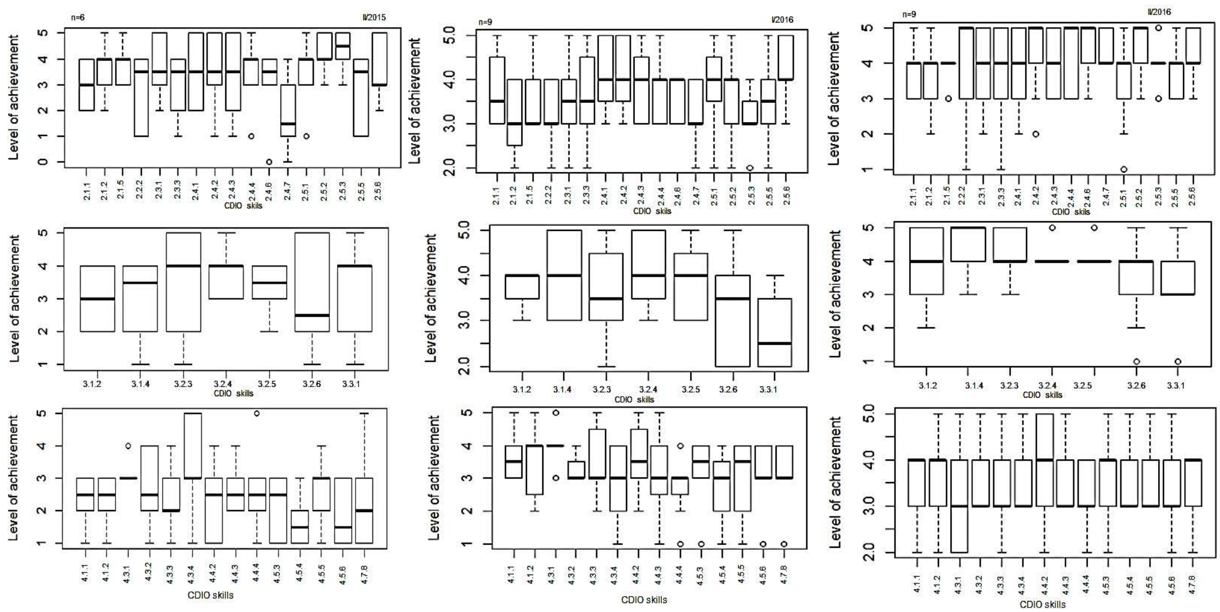

Figure 7. Second milestone proficiency level perception data distribution: Databases

Figures 6 and 7 show the data distribution of student proficiency level perception for the first and second milestones. Course sizes are shown in the top row. Data distributions in Figure 6 show less variance in student perceptions for semesters 2015-II and 2016-II than for semester 2016-I. This may be explained by noting, as mentioned before, that this course is taken mainly by students that have already failed the course once. In general, data distributions for the second milestone show large variance and correspond to courses taken by less than 10 students. Also, it is more common to find the median of the student perception of their proficiency levels at a higher value for their personal and interpersonal skills than for their skills specific to the engineering profession (level 4).

CONCLUSIONS

Even though our results are preliminary, they are useful in managing both students' and instructors' expectations for the student proficiency levels. Sharing these results among instructors helps them develop realistic expectations of students' proficiency levels at each milestone and take timely actions to address student shortcomings in the following courses. Sharing these results among students helps them know what is expected of them at each milestone, so students become more conscious and responsible for their expected progress in achieving the program learning objectives. To this extent, we are working on improving the dissemination of these results among students and on gathering more data so as to have statistically significant data that guides our program improvement process.

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