CDIO PROGRAM EVALUATION ADAPTED TO ABET CRITERIA

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Abstract

The present article describes the evolution of the evaluation model developed by the Electronics Engineering (EE) Program at Pontificia Universidad Javeriana. This model adapts the CDIO evaluation approach to the ABET accreditation criteria. The original model structure was based on the annual evaluation of program outcomes performance, analyzing the levels reached by the student population and gathering evidence for the self-study report. Here, annual rubrics were established for each competence integrated in the curriculum, and from the incidence matrix (courses responsible for the development of the outcomes), a group of courses was selected for evaluation.

The main problem of the proposed model was the management of the extensive amount of information, making the analysis and competence traceability difficult. In this sense, an evolution of the model was proposed, in which the CDIO competences (integrated in the curriculum) were grouped using a direct mapping with the eleven ABET outcomes. In addition, the annual rubrics, specific for each of the CDIO syllabus competence, were transformed into performance indicators of the ABET outcomes, thus simplifying the report and evidence gathering process. Furthermore, the evolution of the model allowed to improve the process of outcome analysis, to a more effective program evaluation process, including improvement actions to short and medium term, and feedback for continuous improvement.

Keywords: active learning; engineering education; CDIO approach

Resumen

El presente artículo describe la evolución del modelo de evaluación desarrollado por el Programa de Ingeniería Electrónica de la Pontificia Universidad Javeriana. Este adapta el modelo de evaluación enmarcado en la filosofía CDIO a los criterios de la acreditación ABET. La estructura del modelo original estaba basada en una evaluación anual del desempeño en los outcomes (resultados de aprendizaje) del programa. En este se analizaban los niveles alcanzados por los estudiantes y se recolectaban evidencias para el informe de autoevaluación. En este modelo, se establecieron las rúbricas anuales para cada competencia integrada en el currículo, y a partir de la matriz de incidencia (cursos responsables del desarrollo de los resultados de aprendizaje), se seleccionó un grupo de cursos para realizar la evaluación.

El principal inconveniente del modelo propuesto fue el manejo de la extensa cantidad de información, haciendo que el análisis y la trazabilidad de las competencias fuera muy difícil. En este sentido, se propuso una evolución del modelo en la cual se agruparon las competencias CDIO (integradas en el currículo) utilizando un mapeo directo con los once outcomes ABET. Adicional a esto, se transformaron las rúbricas anuales, específicas para cada una de las competencias CDIO, en indicadores de desempeño para los outcomes ABET, simplificando de este modo el informe y el proceso de recolección de evidencias. Más aún, la evolución del modelo permitió mejorar el proceso de análisis de cada outcome hacia un proceso de evaluación del programa más efectivo, incluyendo acciones de mejora corto y mediano plazo, y realimentación para el mejoramiento continuo.

Palabras clave: *aprendizaje activo; educación en ingeniería; iniciativa CDIO*

1. CDIO program evaluation model

Since 2010, the EE program has been involved in a curricular review towards the implementation of the CDIO™ Initiative. The EE program is adopting CDIO in order to improve the education of engineering with a comprehensive education that takes into account the local and global context with a very high emphasis in the construction product life cycle (Crawley, et al. 2014). Furthermore, the EE program has used CDIO as the framework of his curricular planning, outcome based assessment and program evaluation strategy.

In order to implement this curricular reform, the EE program has been working on each of the 12 CDIO standards, highlighting *Standard 11* and *12*. *Standard 11* is closely related with the assessment of student learning in personal and interpersonal skills; product, process and system building skills; as well as disciplinary knowledge. Additionally, *Standard 12* aims for developing a system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for continuous improvement purpose.
As mentioned, CDIO™ Initiative is a framework of the curricular planning and outcome-based assessment. For instance, the EE program has used the CDIO attributes and abilities to design the assessment tools for the

Student Outcomes. Particularly, *Standard 2* consists in the group of specific, detailed learning outcomes for personal and interpersonal skills; product, process, and system building skills; as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders (Craig, J).

The classification of the CDIO attributes and abilities has three different levels. The most general level classifies attributes and abilities according to four categories: 1. Technical knowledge and reasoning. 2. Personal and professional skills and attributes. 3. Interpersonal skills: teamwork and communication. 4. Conceiving, designing, implementing and operating systems in the enterprise and societal context. The second level classifies attributes and abilities according to 17 categories. Figure 1 shows the CDIO Syllabus.

1 DISCIPLINARY KNOWLEDGE AND REASONING
1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCE
1.2 CORE FUNDAMENTAL KNOWLEDGE OF ENGINEERING
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
2.1 ANALYTICAL REASONING AND PROBLEM SOLVING
2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY
2.3 SYSTEM THINKING
2.4 ATTITUDES, THOUGH AND LEARNING
2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
3.1 TEAMWORK
3.2 COMMUNICATIONS
3.3 COMMUNICATIONS IN FOREIGN LANGUAGES

4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT
4.1 EXTERNAL, SOCIETAL AND ENVIRONMENTAL CONTEXT
4.2 ENTERPRISE AND BUSINESS CONTEXT
4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT
4.4 DESIGNING
4.5 IMPLEMENTING
4.6 OPERATING

Figure 1. CDIO Syllabus.

The general assessment system is fed through the educational results and the rubrics of the courses to have a systemic perspective of the goals reached by the cohorts and the effectiveness of the curriculum (García, et al. 2001). Based on the CDIO Syllabus, annual rubrics were defined for each of 70 abilities and attributes selected for the EE program. The annual rubrics correspond to specific outcomes that students are required to demonstrate at a minimum expected level each year. There are annual rubrics for Years 1 to 5 (10 semesters), so that the same attribute has five different levels of attainment or rubrics per year. Furthermore, each course of a specific year has to assess the corresponding rubrics of that year. Likewise, these detailed rubrics are used to assess students.

The courses that belong to one year are responsible for different skills, attributes, and levels of competence. In this sense, the professors must teach and evaluate all the elements included therein. Then, pursuant to learning assessment of the students, the professor is in charge of assessing, through annual rubrics, the level of competence of the group, vis-à-vis each objective for the year. Each course is responsible for by collecting the activities, learning assessment rubrics, and evidence of the work supporting said evaluation.

Each Outcome of the EE program for a course perfectly fits with the CDIO abilities and the annual rubrics. It is important to take into account that, even though the rubrics were designed to evaluate courses by annual criteria, the assessment is conducted each semester. A performance indicator corresponds to the way the abilities and attributes are evaluated by means of annual rubrics (Cantú, et al. 2007). The notation performance indicator, or simply indicator, is preferred in the assessment analysis and continuous improvement.

The main problem of the proposed model was the management of the extensive amount of information, making the analysis and competence traceability difficult. In this sense, an evolution of the model was proposed in which the CDIO competences (integrated in the curriculum) were grouped using a direct mapping with the eleven ABET outcomes. Then, in order to simplify the program evaluation strategy, the EE program adopted the ABET Student Outcomes:

(a) an ability to apply knowledge of mathematics, science, and engineering.
(b) an ability to design and conduct experiments, as well as to analyze and interpret data.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
(d) an ability to function on multidisciplinary teams.
(e) an ability to identify, formulate, and solve engineering problems.
(f) an understanding of professional and ethical responsibility.
(g) an ability to communicate effectively.
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
(i) a recognition of the need for, and an ability to engage in life-long learning.
(j) a knowledge of contemporary issues.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

CDIO attributes and abilities complement and significantly expand on ABET Student Outcomes (Johns, 2006). For this reason, the EE program used the CDIO abilities and attributes to assess each ABET outcome. In particular, for each a-k outcome, several CDIO abilities and attributes have been defined, facilitating the assessment process. The quantitative way they are evaluated consists of Annual Rubrics and Performance Indicators.

2. Process for the establishment and revision of the student outcomes

The process used for establishing and revising the Student Outcomes is described in Figure 2. This process is applied each semester and revised every two years. It follows the criteria established by ABET. One group of faculty members is designated for applying the assessment tools, whereas a different group, the outcome leaders, is in charge of the final evaluation of outcomes. The improvement actions are discussed by the Curriculum Committee.

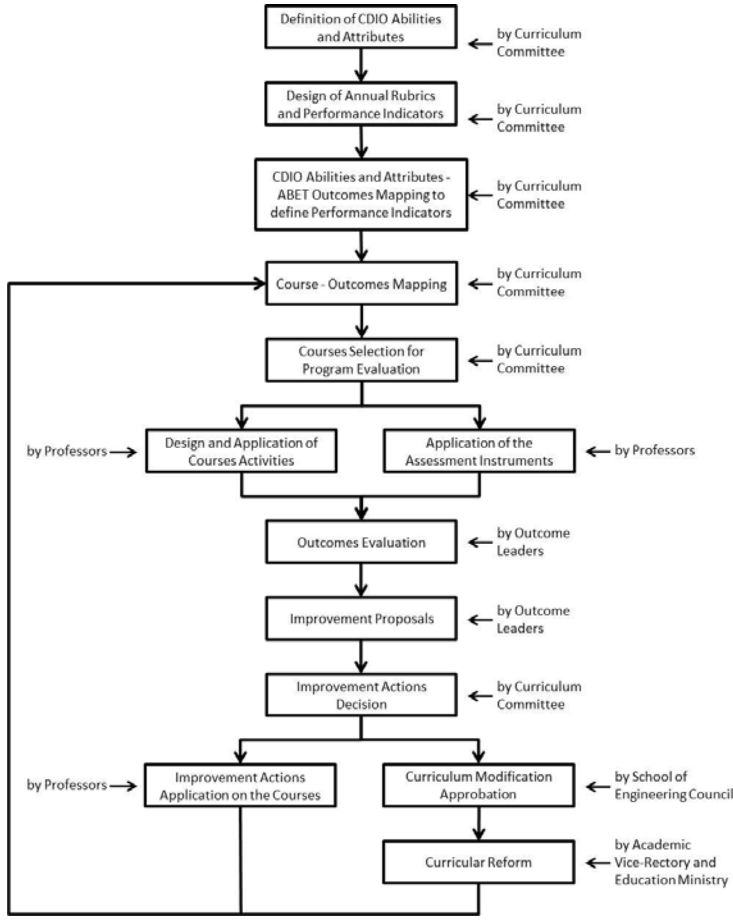

Figure 2. The Process for the Review of Student Outcomes

3. Assessment tools and processes

To gather the data used for the evaluation of each student outcome, indirect and direct measures have been established. Indirect measures consist of a student survey and a questionnaire related to the Capstone Project. For direct measures, two main tools are used. The first one is a standard assessment instrument applied to several courses. The second one is the assessment of the Capstone Project.

Indirect Measures

Survey

The survey provides feedback from students about their strengths and weaknesses, their perspectives of the EE program and the Student Outcomes, and their recommendations. It is an important tool for the continuous improvement process. The survey is conducted with all students in the last semesters (8th, 9th and 10th). It is based on two main questions asked for each of the 11 Student Outcomes:

1) *How important is this outcome to your professional development?*
2) *To what extent has the EE program helped you to develop this outcome?*

Additionally, they are asked about the EE program through these short questions:

1) *What are your primary strengths?*
2) *What are your primary weaknesses?*
3) *Recommendations for changes to the EE program.*
4) *Recommendations to improve student performance in the outcomes.*

Capstone Project Form

This form provides information from students about the design component of their capstone project. The form is also used for program assessment since it provides information about the project's components, which helps to evaluate the outcomes related to it. The form consists of questions about their project in these six areas:

1) Objectives
2) Design Component
3) Design Requirements
4) Design Restrictions
5) Engineering Standards
6) Methodology

Direct Measures

Direct measures are divided in two main groups. First, the Assessment Instrument applied to general courses to assess all of the outcomes, except for Outcome c (engineering design); second, the Capstone Project in which Outcomes c and g (communication) are evaluated.

Assessment Instrument

In order to have a standard tool for the assessment process, an assessment instrument has been designed and implemented. This instrument is based on different elements defined during the five-year curricular review to implement the CDIO Initiative. The instrument is based on the following elements: Annual rubrics and Indicators, CDIO Abilities and attributes – Outcomes mapping, Course selection, Course and Outcomes mapping, and Summary tables.

The instrument is used to directly assess all the outcomes associated with different courses, except for Outcome c, which is evaluated with a different process. To assess the courses in a systematic manner, a shared Google Drive account has been created where the faculty members in charge can fill out the corresponding instruments, upload the evidence and consult the support documents. Each outcome has been assigned to an outcome leader who gathers the information from different courses for this outcome and conducts the assessment.

For each of the 11 Student Outcomes, one or more rubrics have been designed and are summarized below. Each of these rubrics corresponds to the mapping between CDIO abilities and attributes at the second level of detail and ABET outcomes. The attribute Communication in Foreign Languages is not selected for assessment of the EE program; however, this attribute (English) is a prerequisite for graduation.

- **Outcome a (Engineering Fundamentals):** the engineering fundamentals rubrics assess the engineering core as well as the modeling of real world phenomena through basic sciences. These rubrics are based on three areas: mathematical modeling; application of mathematical and scientific concepts; and engineering core.

- **Outcome b (Experimental Skills):** the experimental skills rubrics assess the conception, design, implementation and operation of scientific and engineering experiments. It is based on four areas: hypothesis formulation; survey of print and electronic literature; experimental inquiry; and hypothesis test and defense.

- **Outcome c (Design Skills):** the design skills rubrics assess the conception and application of engineering in systems along with its design, implementation and operation. The rubrics are based on 22 areas: setting system goals and requirements; defining function concept and architecture; modeling of system and ensuring goals can be met; development project management; the design process, design process phasing and approaches; utilization of knowledge in design; disciplinary design; multidisciplinary design; multi-objective design; designing the implementation process; hardware manufacturing; software implementation process; hardware software integration; tests, verification, validation and certification; implementation management; designing and optimizing operations; training and operations; supporting the system lifecycle; system improvement and evolution; disposal and life end issues; and operations management.

- **Outcome d (Teamwork Skills):** the teamwork rubrics assess student leadership and teamwork abilities. These rubrics are based on five areas: forming effective teams; team operation; teamwork growth and evolution; leadership, and technical teaming.

- **Outcome e (Analytical Skills):** the analytical skills rubrics assess the ability to analyze and give solutions to engineering problems. The rubrics are based on three areas: problem identification and formulation – modeling; estimation and qualitative analysis – analysis with uncertainty; and solution and recommendation.

- **Outcome f (Professional/Ethical Responsibility):** the professional/ethical responsibility rubrics are associated with the professional abilities and attitudes students should acquire. They are assessed in three areas: professional ethics; integrity; responsibility and accountability; professional behavior; and external and social context.

- **Outcome g (Communication Skills):** the communication skills rubrics determine the student's communication skills. The areas assessed are four: communication strategy – communication structure; written communication; graphical, electronic/multimedia communication-graphical communication; and oral presentations and interpersonal communications.

- **Outcome h (Impact of Engineering Solutions):** the impact of engineering solutions rubrics coincide perfectly with the conception of systemic thought associated with the comprehension of the context in which the solution is given. The rubrics are based on three areas: system thinking; external and social context; and enterprise and business context.

- **Outcome i (Life-Long Learning):** the life-long learning rubrics are related to professional and personal attitudes and abilities that recognize the necessity to engage in life-long learning. There are four areas related to the rubrics: survey of print and electronic literature; curiosity and life-long learning; proactively planning for one's career; and staying current on world of engineering.
- Outcome j (Contemporary Issues): the contemporary issues rubrics assess the ways students use their knowledge in engineering world contexts. These rubrics are based on two areas: staying current on world of engineering; and external and social context.

- **Outcome k (Modern Engineering Tools):** the modern engineering tools is mainly based on computing, design and personal abilities that allow the engineer to develop as a professional in real world situations. It is assessed by eight main areas: computing and simulation; design methodologies; initiative and willingness to take risks; perseverance and flexibility; creative thinking; critical thinking; awareness of one's personal knowledge, skills, and attitudes; and time and resource management.

Capstone Project

In the capstone project, students choose, formulate and solve applied electronics engineering problems. The assessment of these projects provides data for evaluating Outcomes c and g. The evaluation has four main aspects: the development process, technical report quality and clarity, oral presentation quality and clarity, and functional testing. Each aspect has a different percentage value and is evaluated by two juries and project adviser. General observations are also made, and a final grade (0-5) is determined by the evaluation committee. These aspects as well as the observations are used for the assessment process.

An assessment instrument similar to the ones applied in other courses was designed to assess the outcomes related to this project. The instrument also unifies the annual rubrics that correspond to Outcomes c and g, and also have summary tables to facilitate the task of the assigned evaluator.

The main difference with the instruments described in the previous section is that it is applied individually to each student and not to the whole course. Therefore, no percentages are used. The project director uses the instrument to determine the performance of the student with the different rubrics by selecting the performance criterion. Once instruments are complete, a summary table is filled out and the outcome is given to the outcome leader.

4. Conclusions and future work

The evolution of the evaluation model developed by the EE Program at Pontificia Universidad Javeriana is presented. The general assessment system is fed by the educational results and the rubrics of the courses. This is used to have a systematic perspective of the goals reached by the cohorts and the effectiveness of the curriculum. Professors are responsible of the evaluation by developing the activities, learning assessment rubrics, and by providing the evidence that support it. Indirect and direct measures are used to collect information for the evaluation of each student outcome. Indirect measures consist of a student survey and a form related to the Capstone Project, while direct measures are based on a standard assessment instrument. The rubrics that have been designed are also presented in this article.

As future work, the EE program is working on the systematization of the assessment process. For this, a simplification of the process is necessary. The performance indicators will be reduced, to those that really apply to the program. The 5-year evaluation will be transformed to a 3 times evaluation with beginner-intermediate-advanced courses. Furthermore, the specific activities to evaluate the outcomes will be homogenized throughout courses and professors. This will facilitate the comparison and analysis processes between courses and years.

In the future, the systematization of the process will keep track of each student and therefore the cohorts. The information collected from these tests allows continuous improvement actions rise about courses. These improvements include changes in the learning outcomes of courses, changes in practice learning and assessment; and ongoing monitoring of laboratory resources and workspaces. For the EE program is important work ongoing reflection on the 12 CDIO standards applying international guidelines such as those proposed ABET, so that a mechanism of self-regulation process is continuously implemented.

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