A SYSTEMIC APPROACH IN AN ELECTRONICS ENGINEERING CURRICULUM

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ABSTRACT

This article describes the process followed by the Electronics Engineering Program in order to redesign its program using a CDIO-based approach. The new structure of the curriculum in the program was conceived from the solving problem paradigm. In that sense, we are looking for a systemic perspective of learning to improve the application ability of the engineering students. It means the new curriculum searches that students will be able to analyze the context identifying the problems and from that point, developing different general skills and tools from the discipline to solve the problems. This is indeed, a curriculum with a top down fabric that agrees with a constructive alignment composed by three particular emphases, which come from the Colombian needs: Communications, controls and energy, digital systems and signal processing. In this context, the student will conceive, design, implement and operate complex engineering systems in these areas. The presented emphases are the final stage of a formation plan which begins understanding the physic phenomena and the different mathematical tools that simplify those phenomena through signal processing which in our case is a fundamental part of the curriculum. This is why our program has an intensive formation in signal processing since the first year. We strongly believe that an electronic engineer requires to understand how to process a signal in a digital or analogic way.

The first part of the article explains why a new program is necessary. Then, it is explained how the different competences are taken into account. After that, general structure of the curriculum is presented where each unit is described. Some preliminary results are given since this new curriculum is currently being implemented. The final part of the paper is devoted to conclude and identify the future work.

This is a novel approach in Colombia. The electronics program from our university is the first accredited program that implements the CDIO methodology in the country.

KEYWORDS

Competences, Standard 3, Electronic Engineering, units.

INTRODUCTION

Electronics studies the characteristics and properties of the fundamental elements with which electrical current can be manipulated (usually of low intensity) in multiple ways. It conceives systems that provide a solution to practical problems of the society, both in the industrial environment and in everyday life.

The experiments carried out by different scientists in the late nineteenth and early twentieth centuries in terms of electrical and electromagnetic phenomena were the bases for electronic engineering. In 1884, Thomas Alva Edison detected the phenomenon that would give rise to the first "electronic valve" called a diode. In 1907, Lee de Forest trying to perfect the telegraphic receivers added a grid between the cathode and the anode of a diode. This new element was called the triode and is the basis of modern electronics. By the end of the 50s of the twentieth century, the triode evolves in the transistor, which revolutionized electronics. The transistor is indeed the basic element for the integrated circuits. Those reasons caused the need of specific engineers throughout the world. Colombia, does not escape from this boom and by the year 1960, the Faculty of Electronic Engineering of La Pontificia Universidad Javeriana was created. The main objective of the new faculty was written as: "The training of professionals whose scientific and moral preparation will enable them to perform excellently the profession". The duration of the studies was five years just like today. Very important for the good start of the Faculty was the great collaboration given by industries like Philips, Siemens and Ericsson.

Since its creation, the Electronic Engineering Career has systematically worked on its continuous improvement through four reform processes. In the 70s, a curricular plan was designed that gave importance to the subjects of the discipline. In the 80s, fundamentals of physics and mathematics were strengthened, increasing the courses in basic sciences. This was carried out to respond to the demands of the engineering industry with a scientific formalism. At the beginning of this century, a third reform aimed at the flexibility of the curriculum and a 1/2 distribution was implemented (1 hour of face-to-face work time per 2 hours of independent work time). This was in tune with the Mission and the education project which were formulated in 1992.

Since electronic engineering has been evolving, the device approach has been changed to a completely systemic approach. Moreover, Colombia is not a technology producing country and when this is required, it can generally be imported from other countries that have sufficient resources for the development of specialized devices. These reasons require that the electronic engineering in the country turn to an aspect mainly towards applications and towards the development of algorithms, of course without leaving aside the basic concepts of the device. Responding to these needs and in convergence with the guidelines of the University, CDIO Initiative promoted the design of an integrated curriculum which has as its central axis the cycle of development of products, processes and systems (CDIO cycle) (Al-Atabi, M., 2013). Thus, it must integrate, in equal parts, the disciplinary knowledge of engineering, the demands of the social context, the electronic industry and non-disciplinary skills and abilities (Brodeur, B., 2005), (Crawley, E. F., 2007), (Fai, S.K., 2011), (Crawley, E., F., 2014). Indeed, the reform also searches to answer to questions and criticisms of engineering education in the Latin American context, where the lack of industry and the lack of technological generation affect various areas of national development. A new integrated curriculum is generated, with methodological proposals taking into account all of this. This challenges in similar to other cases such as the one presented in (Parashar, A. K., 2012). The new curriculum of the electronic engineering career at the Pontificia Universidad Javeriana focuses on a systemic point of view and it is for this reason that the unit of signals becomes important. This unit is complemented with the area of both analog and digital circuits from the systemic point of view. In this new reform the four parts of CDIO initiative is taken into account: Disciplinary knowledge and reasoning, Personal and professional skills and attributes, Interpersonal skills: teamwork and communication, Conceiving, designing, implementing, and operating systems in the enterprise, societal, and environmental context. All of this applied to the electronics engineering.

This article is distributed as follows: Next section shows how was the process to integrate the non-disciplinary and the disciplinary competence. Then, the curriculum with its different units is presented. After, some preliminary results prove some of the advantages of the proposal and finally conclusions and future work are given.

INTEGRATING COMPETENCES

The formulation of the new curriculum was developed in several stages. First, professors of the Department of Electronics worked in the structural changes of both the curriculum and the teaching / learning methodology. The proposal reform not only modified the structure of the subjects but also the teaching paradigm, to one of active learning based on problem solving, projects, experiences and collaborative (Jamison, A., 2014). Secondly, the personal, interpersonal and CDIO cycles are grouped under the term "non-disciplinary competences" in the new plan, were chosen, formalized and weighted. This set of skills and abilities known as Syllabus CDIO had its respective process of reflection among professors, graduates and members of the industry. The result is an Electronics Engineering program with an adapted CDIO Syllabus that reflects the institutional character (Verhaevert, J., 2016). Competences can be seen in Table 1.

Table 1: List of non-disciplinary competences for the new curriculum of the Electronic Engineering career at the Pontificia Universidad Javeriana.

2.1 ANALYSIS AND SOLUTION OF ENGINEERING PROBLEMS
2.2 EXPERIMENTATION, DISCOVERY OF REALITY AND CONSTRUCTION OF KNOWLEDGE
2.3 SYSTEMIC THINKING
2.4 PERSONAL ATTITUDES AND SKILLS
2.5 PROFESSIONAL CAPABILITIES AND ATTITUDES
3.1 TEAMWORK
3.2 COMMUNICATION
3.3 COMMUNICATION IN FOREIGN LANGUAGES
4.1 SOCIAL AND EXTERNAL CONTEXT
4.2 BUSINESS AND BUSINESS CONTEXT
4.3 CONCEIVING AND APPLYING ENGINEERING TO SYSTEMS
4.4 DESIGN
4.5 IMPLEMENTATION
4.6 OPERATE

In third place, once the competences were established and the profile of the graduate was defined, the reflection and reformulation of the disciplinary contents was started. For this, backward design technique was used in order to obtain the subjects of the new curriculum (Brodeur, B., 2005), (Crawley, E., F., 2011).

Once the disciplinary contents have been determined, they are integrated into the adapted CDIO Syllabus. It identifies the learning sequences associated with each competence and content according to the expected development of each one and taking into account the different training moments. The results from this methodology is shown in the next section.

Development of content and competences depends on integrated active learning, in which students put into practice the skills of training through teaching / learning activities that promote disciplinary content. Active learning is based on activities where students simulate the professional practice of engineering. This requires them to apply, analyze and evaluate ideas. Moreover, they have to solve problems of the discipline since the first semester. In this way they understand the concepts and develop the skills of the training plan.

The following section describes the result obtained from this job of integrating competencies with the disciplinary skills.

THE NEW ELECTRONIC ENEGINEERING CURRICULUM

General description

As mentioned above, the new curricular structure of the Electronic Engineering program was developed as a result of a continuous reflection of the program, attending to the requirements of the actors of the context (industry, unions, graduates, students and teachers). A 5-year structure was created with courses in charge of developing the students' skills, knowledge and skills necessary for their professional practice (González, A., 2016).

This curricular structure, includes 51 articulated courses following the institutional policies and the disciplinary, integral and flexible guidelines of the program. It has a total of 160 academic credits. The component of the fundamental core represents 68% of the plan including the mathematics, physics, engineering, and institutional lines.17% of the academic credits are assigned to the emphasis of the discipline and 14% corresponds to subjects of free choice. Moreover, the new curriculum presents particular characteristics compatible with the guidelines of the context offered by the CDIO philosophy:

- Engineering introduction course in first semester, which is characterized as a primary design and construction experience.
- Courses in physics and mathematics aligned with the courses of the discipline that integrate general competences
- It starts disciplinary formation from first semester.
- Two additional design and construction experiences are given: one in the third year and one in the fifth year.
- Balanced academic load, related to the total number of courses.
- Innovative practices of teaching, assessment and work spaces.
- It has balance between the theoretical topics and practical ones.
- Rising relationship with industry.
- A program to promote the retention of students.
- Subjects of humanistic areas are connected from the discipline.
- Integrated training in skills different to disciplinary ones.

The Electronics Engineering curriculum was designed from a systemic perspective. In this sense, the disciplinary training begins uninterrupted from the first semester. It is approached from the construction of a background related to the cycle of identification and formulation of problems. In this context, solutions are technological and the object of design corresponds to an electronic system. From the first year of training, students are faced with knowing the context and their problems. They understand the responsibility they acquire as a professional. The solution of problems in the real world implies the development of a graduation profile with knowledge and technical skills. Moreover, a group of general competences are given that will allow the graduate to profess with excellence their discipline. A gradual learning of personal, interpersonal skills and CDIO determines the scope of each of the year. Integration of these competences requires a curricular design based on training results that combine technical and disciplinary skills as well as general competencies (communication, teamwork, etc.). At this point, the viability of an integrated curriculum is generated in the choice of some issues, which are really essential for the formation of the student, especially in the areas of mathematics, physics and engineering (Fai, S.K., 2011), (Jamison, A., 2014). These disciplinary concepts are called nuclear competences and allow the construction of integrated training results with general competencies. The course programs are characterized by including a group of training results, the activities associated with each objective and the learning assessment rubrics that feed the program evaluation model.

Disciplinary units

A general description of the curriculum can be approached from the general objective of the training of electronic engineers. As mentioned before, the goal of the program is to train professionals capable of delivering electronic solutions to the problems of the context. In this sense, the curriculum proposes six disciplinary work units that contain a group of courses dedicated to each specific area: physics, mathematics, signal processing, analog systems, digital systems and CDIO project unit. The distribution of lines is shown in Figure 1.

The Physics unit is responsible for developing the learning of physical phenomena, which form the context that an electronic engineer must know. These phenomena are the elements that will be measured, adapted, processed and returned to the world. The competences associated with these lines are related to the construction of knowledge, data analysis and work in the laboratory.

The way to capture the information of the world and return it to it, is carried out by electrical signals. Thus, this becomes the object of study of electronic engineering. That is why a unit of signals processing is developed. The signals represent physical phenomena, their nature in multivariate and complex. In this sense, the courses of the unit become a context to develop the skills of the cycle of identification and formulation of problems associated with the area of signals.

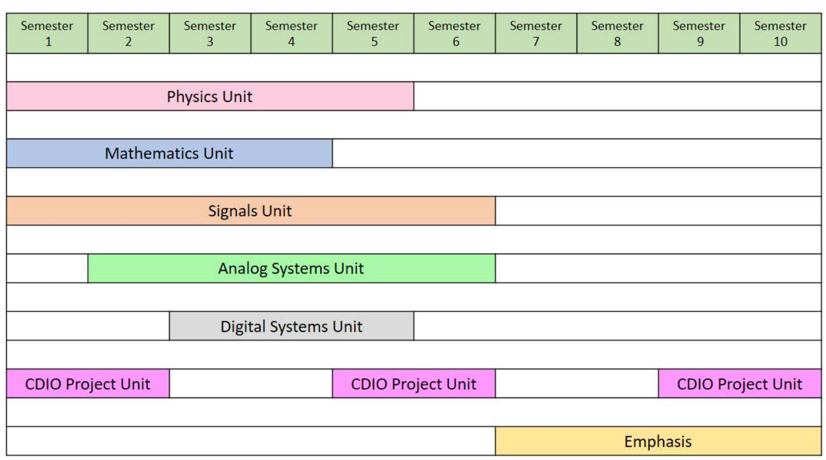

Figure 1: List of units for the new curriculum of the Electronic Engineering

The conditioning, processing and communication of signals requires technological tools that correspond to electronic systems. At this point the Analog Systems Unit provides circuit analysis tools and develops the understanding of the operation of analog electronic devices. The perspective of the courses is systemic and allows the development of holistic thinking as a tool for problem solving.

Digital systems unit provides training in digital processing tools and devices and hardware development for a particular solution. The competences developed are associated with the product construction cycle.

Finally, skills, knowledge and competences developed in those lines are integrated through the design and construction experiences belonging to the CDIO project unit. These are characterized as projects in the real context of the industry or the research groups of the engineering school. The projects integrate general skills such as teamwork, communication skills, project management and again expose the student to the CDIO cycle. The relationship between the different units and competences is shown in Figure 2. During the fourth year, students have the option of choosing an emphasis which comes from the Colombian needs: Communications, controls and energy, digital systems and signal processing. In this context, the student will conceive, design, implement and operate complex engineering systems in these areas.

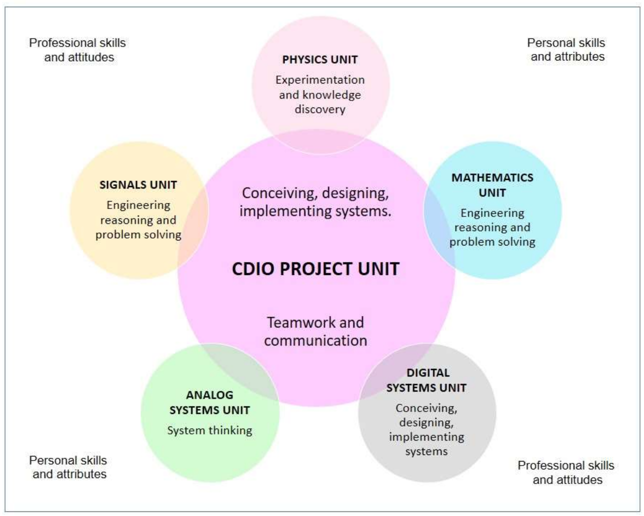

Figure 2: List of non-disciplinary competences with the units.

The curriculum is currently implemented until the 4th semester. Next section shows some results obtained in the implementation of this curriculum.

PRELIMINARY RESULTS

In order to measure the impact of the same in the learning of competences and contents, a survey was designed. Students could answer it voluntarily. 68 students responded from 231 active students in the new curriculum. This is 33% of the population. The questions were of the multiple choice type with 5 possible answers. This survey measures the quality of each one of the non-disciplinary competences developed within the program and the skills of the CDIO curriculum. The followings questions per competence (Analysis and problem solving, Experimentation, discovery of reality and construction of knowledge, Systemic thinking, Personal attitudes and skills, teamwork, communication, Design) were:
a) Do you think that the competence is developed in the program?
b) About quality, at what level is this competence developed?
There were also similar questions about basic abilities (Mathematics and Physics):
a) Do you think that the basic ability is developed in the program?

b) About quality, at what level is this basic ability developed?

Test 1: Non-disciplinary Competences

Table 2 shows the perception in percentage that students have about the non-disciplinary competences from table 1. Notice that not all the competences given in table 1 are analyzed. This is because some of them are introduced after third year (5th semester). About the competence "Analysis and problem solving" competition, 78% thinks that the quality with which this competence is developed is very high or high. 7% of the population thinks that it has an average quality, low or very low. Regarding the competence of experimentation, discovery of reality and construction of knowledge, the behavior is very similar. 74% has the opinion that the implementation of this competence in the CDIO classes of the Electronic Engineering Program of the Pontificia Universidad Javeriana is very high or high, 21% considers that quality is average. Results for the systemic thinking competence show that students consider it high or very high quality obtaining and 56%. Only 8% considers that quality in this competence is low or very low and the rest of the population think that quality is average. In the case of the competence of attitudes and personal skills, 71% of the population believes that quality is very high or high, 22% considers that quality is average. Regarding competence of teamwork, 82% of the population considers that the quality of this competition is very high or high and 18% of the population remaining is distributed among medium, low or very low quality. The communication competence has a perception of very high or high quality among students of 60%. 35% considers communication competence to be average. For the design competence, 59% of students considers that it is high or very high quality in the courses of the program. Figure 3 shows the perception in number of students with respect to each disciplinary competences.

Table 2: Perception of students against the quality of competencies in percentage.

Competences	Very high	High	Average	Low	Very Low
2.1	19%	59%	19%	3%	0%
2.2	24%	50%	21%	3%	3%
2.3	13%	43%	35%	7%	1%
2.4	24%	47%	22%	4%	3%
3.1	51%	31%	10%	6%	1%
3.2	19%	41%	35%	1%	3%
4.4	25%	34%	34%	6%	1%

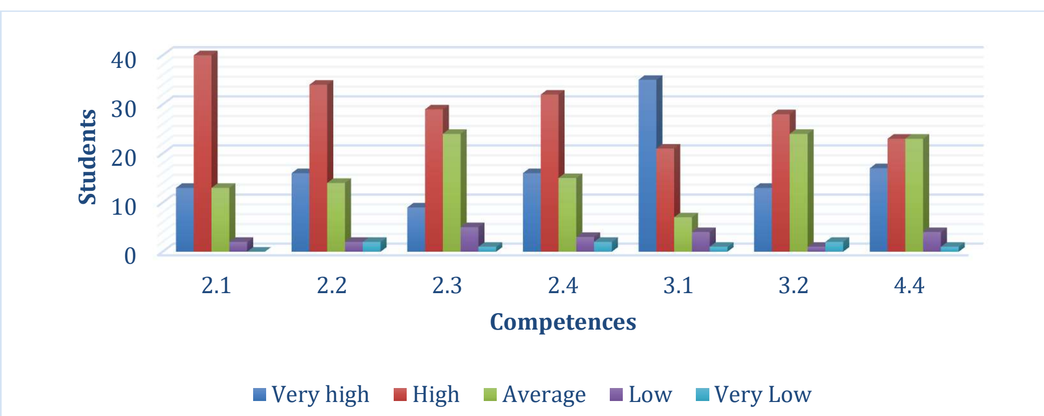

Figure 3: Perception of students regarding the quality of competencies in the number of students (See competences in table 1)

As it can be seen, the perception is in general very good. There is some improvement to be implemented mainly in the competences of Systematic Thinking, communication and design. One solution is a mentor program among others.

Test 2: Basic abilities

It was also measured the perception of the students in terms of two basic abilities: Mathematics and physics. For mathematics ability, 84% considers that the development of these skills is very high, high or average. Only 16% thinks that the quality is bad or very bad. Regarding the ability of physics, the students' perception is that 81% of this skill has very high, high or average in the development of the courses developed under the CDIO standards. These results are summarized in Table 3. Figure 4 shows this behavior with the number of students.

Table 3: Perception of students against the quality of skill development

Abilities	Very high	High	Average	Low	Very Low
Mathematics	25%	34%	25%	12%	4%
Physics	22%	44%	15%	13%	6%

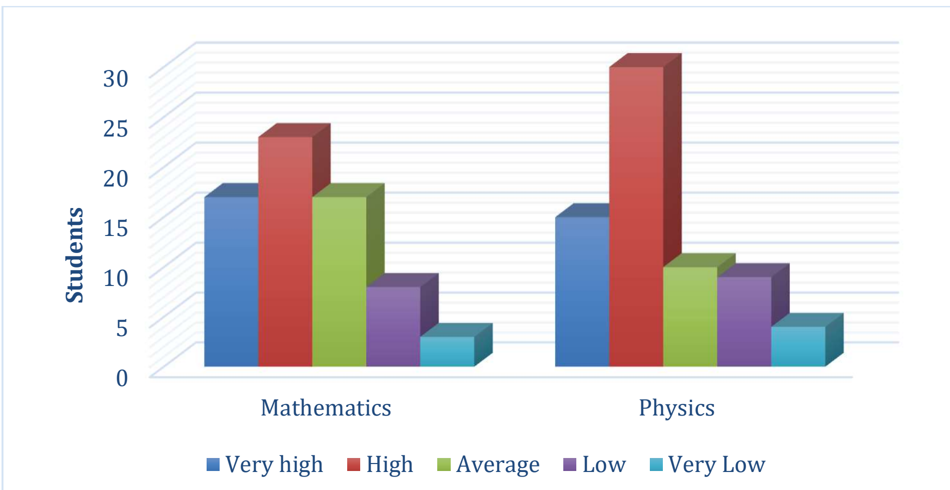

Figure 4: Perception of students against the quality of the development of skills in number of students.

From this test, it can be concluded that physics has a very good perception. This is due to the increase of contact hours in those courses. Mathematics need some improvements in order to rise up the quality.

Test 3: Academic states

A comparison is then made between the academic states of the students that are part of the old plan and the new CDIO plan. Both populations are different in size, and the behavior of both is very similar in terms of academic status and academic mortality. In the university, there is two warnings that the students receive. The first warning appears when the GPA is less than 3.4/5.0. A second warning appears if after being in first warning, the GPA continues to be in 3.4/5.0. Figure 5 summarizes the academic states of the students. As it can be seen, the exclusion in both cases is very similar. Exclusion is 3% for the new program. For the old program is 4%. 6% of students for the new program have second warning and for the old plan is only 2%. This is a point also to improve in the future work.

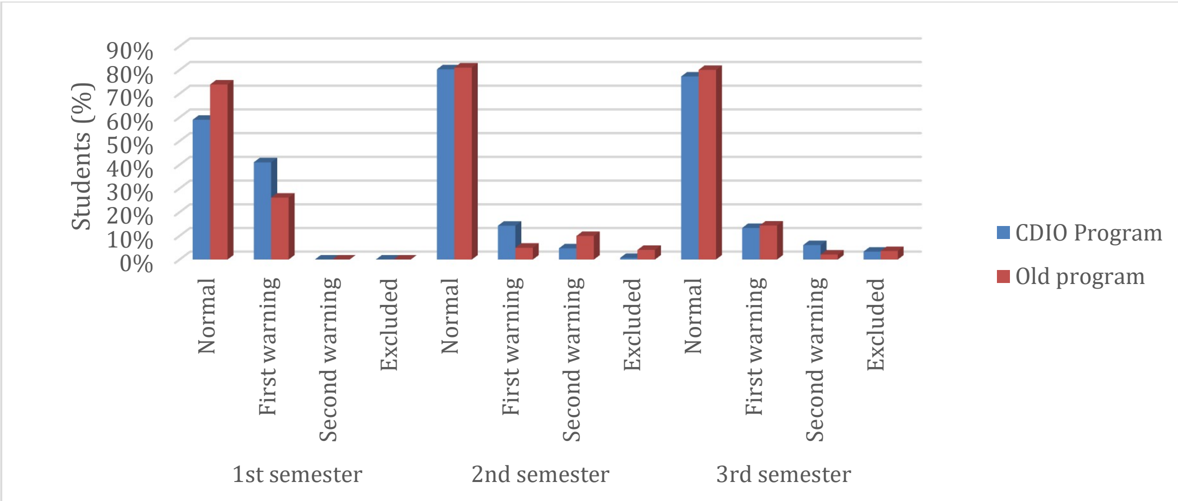

Figure 5: Comparison of academic states. CDIO Program and Old Program.

CONCLUSIONS

In this article, it was shown the process that we used in La Pontificia Universidad Javeriana to implement the CDIO methodology in Electronic Engineering. Indeed, this methodology is adapted to form the new program. The article showed how this adaptation was carried out by the professors. It also shows the units that were mapped with non-disciplinary competences. Perception of the students is in general positive. Some other measurement must be carried out. However, these results also show some challenges regarding particular competences. This program needs a continuous evaluation culture which allow to manage a continuous improvement leading to effective changes in the courses. These changes imply, among other elements, the reorientation of training results, rubrics and scope of the courses. For that reason, ABET will be used as evaluation model in the future. The performance of the students' needs also to be identified in order to give accompaniment to ensure student success. Regarding this point, a program was designed that includes mentoring strategies, reinforcement workshops in basic math and communication skills, among others.

REFERENCES

Al-Atabi, M. (2013). Grand Challenges for Engineering and Development of CDIO Skills. Proceedings of the 9th International CDIO Conference, Cambridge, MA, USA.

Brodeur, B., & Crawley, E. F. (2005). Program Evaluation Aligned With the CDIO Standards. Proceedings of the 2005 ASEE Conference.

Crawley, E. F., Malmqvist, J., Östlund, S., & Brodeur, D. (2007). Rethinking Engineering Education: The CDIO Approach, 1st edition. New York: Springer-Verlag.

Crawley, E., F. Malmqvist, J., Östlund, S., Brodeur, D., & Edström, K. (2014). Rethinking Engineering Education: The CDIO Approach, 2nd edition. New York: Springer-Verlag.

Crawley, E. F., Malmqvist, J., Lucas, W., & Brodeur, D. (2011). The CDIO Syllabus v2.0. An Updated Statement of Goals for Engineering Education. Proceedings of the 7th International CDIO Conference, Lyngby, Denmark.

Fai, S.K. (2011). An Observational Study of Infusing Design Thinking into the CDIO Framework. Proceedings of the 7th International CDIO Conference, Lyngby, Denmark.

González, A., Hurtado, J., Renneberg, K., Bravo, F. & Viveros, F. (2016). Active Learning in Electronics Engineering at Pontificia Universidad Javeriana. Proceedings of the 12th International CDIO Conference, Turku, Finland, June 12-16 2016.

Jamison, A., Kolmos, A. & Holgaard, J. E. (2014). Hybrid Learning: An Integrative Approach to Engineering Education. Journal of Engineering Education, 103(2), 253-273. doi:10.1002/jee.20041.

Parashar, A. K., & Parashar, R. (2012). Innovations and curriculum development for engineering education and research in India. International Conference

Verhaevert, J., & Van Torre, P. (2016). On Design-implement Projects in Electronic Engineering. Proceedings of the 12th International CDIO Conference, Turku, Finland, June 12-16 2016.

BIOGRAPHICAL INFORMATION

Alejandra Gonzalez, Ph.D is an Associate Professor in the Department of Electronics Engineering at the Pontificia Universidad Javeriana, Bogotá, Colombia. Alejandra’s research interests include embedded systems, digital systems design, high-level systems design, artificial intelligence, robotic and curricular management.

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