CHALLENGES IN THE IMPLEMENTATION OF A CDIO CURRICULUM FOR A PROGRAM IN ELECTRONICS ENGINNEERING

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ABSTRACT

The electronics-engineering program at the Pontificia Universidad Javeriana has been implementing, over the last three years, a reform based on the CDIO philosophy. The program has its focus on the solution of real problems with electronics engineering. This philosophy involves different challenges at the level of implementation. Then, it is necessary to look for standardizing, improving and optimizing curricular processes. In addition, this transformation implies operational risks, which are inherent in having several curricula simultaneously. Indeed, each one has different approaches to learning-teaching methodologies. These risks are mainly the faculty overload and its resistance to change, taking into account the development plan and expectations of each of the professors within the institution.

Additionally, the reform implies administrative strategies that guide the implementation and operation stages. This leads to the training of professors in the design of course programs, review of the coherence between the competences and the disciplinary lines, and the evaluation of the program for continuous improvement. All the elements of curricular management plus the need for training in the learning-teaching and assessment methodologies, constitute a new dimension in the CDIO standards 9 and 10.

The management processes, aligned with the philosophy of the university, have required reaching a consensus on what and how to develop the subjects and competencies to ensure learning and high quality of teaching within the framework of the institutional mission. All efforts have demanded professors to incorporate new tasks into their work routines. This generates even tense work environments within the group.

This paper describes the process of implementation and operation of the new curriculum. It begins with a general description of the new program and a comparison with the old one. Then it shows the methodology that has been followed for implementation over the three years and ends with recommendations that reveal the perception by the professor's body about the process.

KEYWORDS

Standards: 3,4,5,7,9,10.

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The main challenges of the implementation of the CDIO methodology to the engineering education lies in integrating the professional, personal and interpersonal skills in the learning process. This paradigm seeks to keep in the curriculum the disciplinary content and teaching of technical and scientific knowledge (Andersson & Andersson, 2010), responding to the needs of the country and industry.

One way to address these challenges is to consider the implementation of professional, personal, and communication skills within engineering teaching methods. The incorporation of these methods is based on the choice of teaching methodologies with the objective of creating the context in which the students of engineering learn the knowledge of their careers and open spaces for the interrelation with the professors and their classroom classmates to facilitate the learning of professional and personal skills. Other topics to consider are the nature of professional skills and competencies in the field of engineering and how these skills develop within classrooms. In the case of CDIO philosophy, this approach is manifested, for example, by a greater integration of the different subjects of the program and active and experiential learning through design and implementation projects.

The strategies for the implementation of the CDIO methodology are based on:

- Curricular reform in order to ensure students have the opportunities to develop knowledge, qualities and attitudes to conceive and design and implement complex systems and products that meet a particular needs or requirements. (Berggren et al., 2003)
- Improvement of the level of education for the deep understanding of technical and complex information.
- Experimental learning environments making use of joint and collaborative laboratories and workspaces
- Efficient methods of evaluation to determine the quality and improvement of the learning processes, in order to maintain standards and quality.

For the methodology of curricular design under the philosophy CDIO must be taken into account 4 stages, these are carried out within the classrooms and by means of cases of study evaluates their viability: the stage of **conception**, which includes defining the necessity and the technology, considering the strategies, regulations and requirements of the final product. The second stage, **design**, focuses on the approach of architecture that responds to requirements based on plans, drawings, algorithms and describes what you want to implement. **Implementation stage**, this stage refers to the transformation of design into a product, including manufacturing, coding, testing and validation. Finally, **operation** stage, which generates the life cycle of the product which includes installation, maintenance and removal (Berggren et al., 2003). All these stages in order to develop concepts, architectures and methodologies within the academic field and classrooms of students.

THE NEW CURRICULUM VS. THE PREVIOUS CURRICULUM OF ELECTRONICS ENGINEERING FOR THE PONTIFICIA UNIVERISDAD JAVERIANA

Engineering education aims to provide students with sufficient disciplinary knowledge of science and engineering principles so that they can become successful engineers (Andersson & Andersson, 2010). The program of Electronics Engineering includes basic sciences as mathematics and physics, and is orientated the conception, design, integration and development of technology, in multiple areas of the industry and the daily life, to give solutions applied to practical problems.

Among these multiple areas developed in the Electronics Engineering program at Pontificia Universidad Javeriana (PUJ) are: telecommunications, power electronics and renewable energies, industrial control and automation, signal processing, robotics, digital and computer systems, microelectronics, biomedical and many others. All this through the design of digital electronic circuits, analog and system integration.

Overview of the previous program

The curricular approach of the previous program of Electronics Engineering at PUJ has a traditional approach, in which the teaching of disciplinary knowledge is the main and only objective measurable and evaluable (Christensen et al., 2006). Professional and personal skills are expected to be developed implicitly and do not consent, while students devote their time to problem-solving, project development and solution design.

The curricular structure of the previous program includes 56 articulated courses following the institutional policies and the disciplinary, integral and flexible guidelines of the program. It has a total of 174 academic credits. The fundamental core component represents 74.8% of the plan, including the lines of mathematics, physics, engineering, and institutions subjects. The 15.5% of the academic credits are assigned to the emphasis of the discipline and 9.7% correspond to subjects of free choice.

As mentioned above, the objective of the program is to train professionals capable of providing electronic solutions to the problems of the context. In this sense, the curriculum proposes 7 disciplinary work units that contain a group of courses dedicated to each specific area: physics, mathematics, signal processing, analogue systems, digital systems and emphasis. The line distribution is shown in Figure 1.

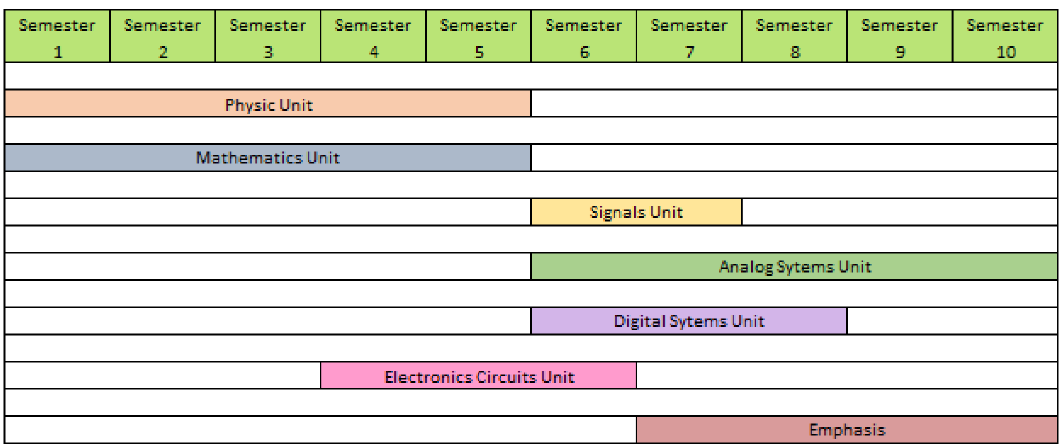

Figure 1. List of lines for the old plan of studies of the Electronics Engineering program of the Pontificia Universidad Javeriana

The old Electronics Engineering curriculum was founded in the first two years as a strong component in basic science and mathematics, with the aim of developing solution-oriented and problem-formulation skills. From sophomore year students, they face more specific problems oriented to electrical circuits and signal analysis. After year three, the program introduces students to components in analogue and digital electronics and a component of emphasis to deepen the subjects of greatest interest of each student.

Overview of the new program

The curricular structure of the new Electronics Engineering program was developed as a result of a continuous reflection of the program, meeting the requirements of the context (industry, professional associations, graduates, students and professors). A 5-year structure was designed with courses in charge of the development of students' skills, as well as the knowledge and skills necessary for their professional practice. (Gonzalez, Patino, Garcia, & Roldán, 2018).

This curricular structure includes 51 courses articulated following the institutional policies and the disciplinary, integral and flexible guidelines of the program. It has a total of 160 academic credits. The core component represents 68% of the plan, including the lines of mathematics, physics, engineering, and institutional courses. 17% of the academic credits are assigned to the emphasis of the discipline and 14% correspond to subjects of free choice. In addition, the new curriculum presents particular characteristics compatible with the context guidelines offered by the CDIO philosophy (Gonzalez et al., 2018) (Gonzalez, Hurtado, Fadul, Sánchez, & Viveros, 2016).

An overview of the curriculum can be addressed from the overall goal of training electronics engineers. As mentioned above, the objective of the program is to educate professionals capable of providing electronic solutions to the problems of the real context. In this sense, the curriculum proposes 6 disciplinary work units, that contain a group of courses dedicated to each specific area: physics, mathematics, signal processing, analogue systems, digital systems and CDIO Project unit. The line distribution is shown in Figure 2 (González, A., 2017).

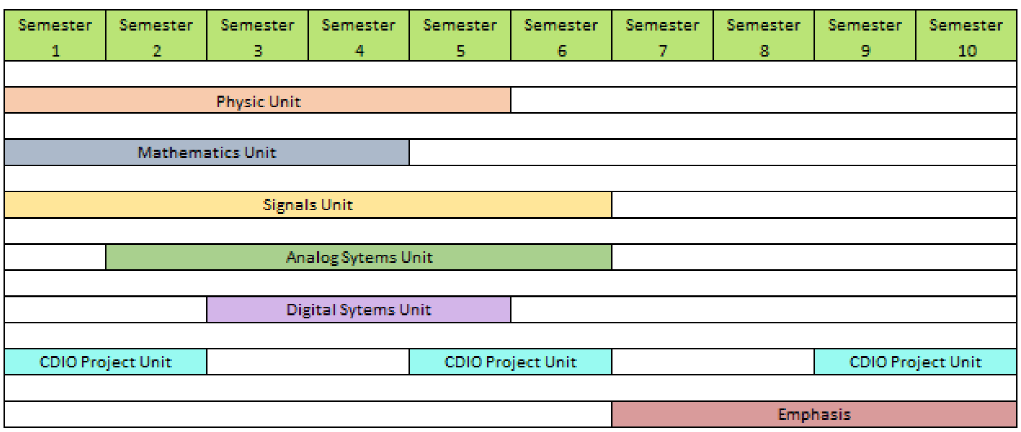

Figure 2. List of competencies for the new curriculum of the program of electronic engineering of the Pontificia Universidad Javeriana

Unlike the previous program, this raises disciplinary learning that begins continuously since the first semester. It is addressed from the construction of a fund related to the cycle of identification and formulation of problems. In this sense, the solutions are technological and the object of design corresponds to an electronic system. From the first year of training, students face knowledge of the context and their problems. The CDIO methodology is selected because this initiative allows to develop the knowledge in engineering and to improve the relevance of the education for the work life (Kontio, 2014).

It is important to emphasize that we focus on gradual learning of personal, interpersonal skills. The integration of these competencies requires a curricular design based on learning outcomes that combine technical and disciplinary skills, as well as general skills (communication, teamwork, etc.). Therefore, the viability of an integrated curriculum is generated in the choice of some topics, which are really essential for the student's training, especially in the areas of mathematics, physics and Engineering (Fai, SK, 2011), (Jamison, A., 2014). These specific concepts of the discipline are called nuclear competencies and allow the construction of integrated training results with general skills and focused on personal and professional skills. The course programs are then characterized by including a group of learning outcomes, the activities associated with each outcome, and the learning assessment rubrics that feed the program's evaluation model.

In addition to curricula, efforts are also focused on faculty, so that they can teach a curriculum with personal and interpersonal skills and building skills of products, processes and systems, integrated with disciplinary knowledge, as described in standards 3, 4, 5 and 7. Then, professors as a collective, have to be proficient in those skills ("Estándares CDIO v.2," 2010). Engineering professors are often experts in research and in the knowledge base of their respective disciplines, but they also tend to have rather limited experience in the exercise of engineering in the industrial and commercial context. Therefore, the university offers courses from the Teaching, Learning and Evaluation Center (CAE+E) to give teachers support and necessary tools to take on the intellectual and personal challenges within their classes. Among the most representative courses, we find: Planning and management of the teaching, resources for the learning: analogues and digitals tools, methods and instruments of evaluation: analytical, planning and management processes workshop, approaches of evaluation for the learning workshop, among others.

METHODS AND CHALLENGES OF IMPLEMENTING THE NEW PROGRAM

As already mentioned, the current program seeks to have as a basis, the solution of problems directly related to electronics engineering under the philosophy CDIO. This philosophy entails different challenges at the level of implementation by faculty, in which we must seek to standardize, improve and optimize processes.

To take on the challenges associated with the implementation, several steps were followed:

1. Introduce the CDIO methodology to faculty and administrators.
2. Help faculty become familiar with CDIO's methodology.
3. Plan the organization, hierarchy and structure of the relevant topics in each line of the program.
4. Reform in the teaching paradigm: Active learning based on problem-solving, by projects, by experiences and collaborative.
5. Plan the interconnection of learning lines.
6. Understand the structure of the course programs from the CDIO perspective: technical knowledge or disciplinary is one of the basic pillars because it provides fundamental knowledge of engineering, knowledge in basic sciences (mathematics and physics).

In the following figure, we can observe the process that has been made for the creation of the course programs based on the CDIO philosophy and with the guidelines of the academic Vice-presidency. Figure 3 shows the iterative process (represented in a closed loop of control) that was carried out until reaching the creation of the course programs and the reforms of all the courses of the plan of studies in Electronics Engineering at PUJ.

The new program references were the academic excellence and the general academic guidelines at PUJ. These two elements allow an integral formation characteristic of our graduates, in which the knowledge is fundamental but one does not leave aside the personal, ethical and social aspects.

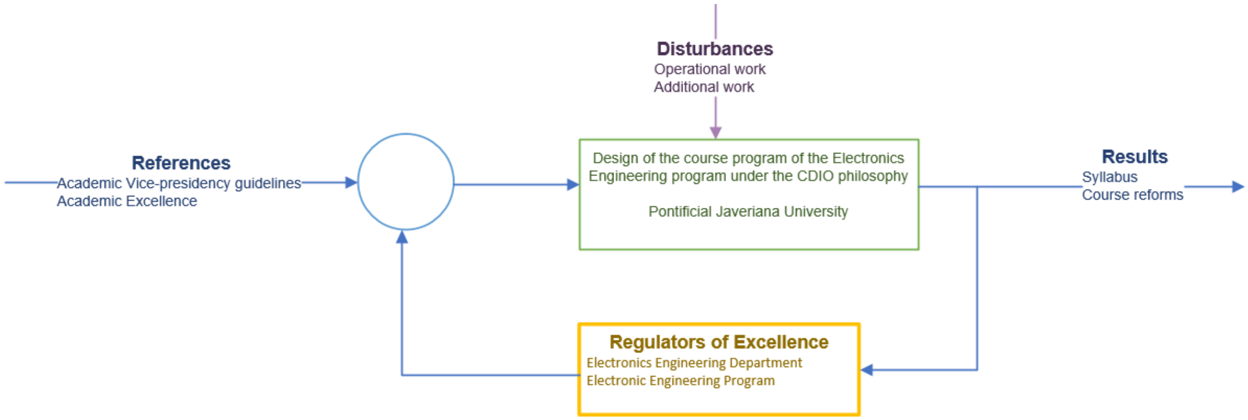

Figure 3. Implementation of the new curriculum of the program of electronic engineering of the Pontificia Universidad Javeriana

In the implementation process, there were some drawbacks or disturbances (represented with purple color). Among them are the operational risks that were one of the hardest to handle. These are inherent to having two curriculums simultaneously, with different approaches to learning-teaching methodologies. This issue mainly generated the workload in the faculty and therefore the resistance to change. Faculty had to design the course programs, in parallel to teach, to carry out research and to maintain the professional development plan within the institution.

In figure 3 the block “regulators of excellence”, is understood as a set of entities that claim programs of the courses are carried out according to the quality expectations, maintaining the curricular contents and the curricular limits within each one of the courses. Additionally, the Program of Electronics Engineering and the Department of Electronics generated spaces for learning and conflict management within the work teams. All processes support the management of laboratory spaces to be more efficient and articulated with the contents and learning objectives of each new course. Spaces of mentoring and advising were created, and their purpose is supplying gaps of knowledge of the students and to support them in their integral formation.

As a result of this iterative process, the new course programs and the corresponding reforms were obtained (Figure 4). The curricular models and designs are based on an organized list of learning outcomes identified as critical in the education of new engineers. In addition to the guidelines, we take into account the identity and ethics as a value of our institution. Finally, surveys were carried out to faculty, students, alumni and industrial representatives to validate the importance of the skills and contents.

PONTIFICIA UNIVERSIDAD JAVERIANA
FACULTAD DE INGENIERIA
ELECTRONICS DEPARTMENT

Pontificia Universidad JAVERIANA Bogotá

Course Name	**Specify the name of the course**
Academic Credits	**4**
Course ID :	xxxx
Level	Haga clic aquí para escribir texto.

1 DESCRIPTION
2 DISCIPLINARY COMPETENCES
3 NO DISCIPLINARY COMPETENCES
4 TEACHING GOALS
5 LEARNING OUTCOMES
6 LEARNING OUTCOMES RUBRIC

Objective 1: Describe the first objective to reach in this course					
Performance indicator	0%	25%	50%	75%	100%
	The student did not reach the goal	The student reached the learning goal by 25%	The student reached the learning goal by 50%	The student reached the learning goal by 75%	The student reached the learning objective

7 PEDAGOGICAL STRATEGIES
8 EVALUATION ACTIVITIES
9 COURSE PROGRAM

Figure 4. Course programs template

In addition, the curricular reform involves administrative strategies guiding the program implementation and the operation. Those strategies lead to train faculty in the design of course programs, review of the coherence between competencies and disciplinary lines, and the evaluation of the program focus on continuous improvement. All the elements of the curricular management mentioned above, together with the need for training in the methodologies of learning-teaching and assessment, constitute a new dimension in the standards 9 and 10 of CDIO.

RESULTS

At present, the course programs of the new program for Electronics Engineering of PUJ are fully developed. In order to measure the perspective of faculty on the development of the new course programs and the reform process, a survey was designed. 17 professors of 24 who were part of the process, responded to the survey, this is 70% of the population.

In the first part of the survey, faculty are asked about the general process. Starting with how many of them had read the manuals for the construction of the course programs. 35% of the professors reported having performed a full manual reading, 47% read the manual partially and the remaining 18% read did not read the manual (Figure 5).

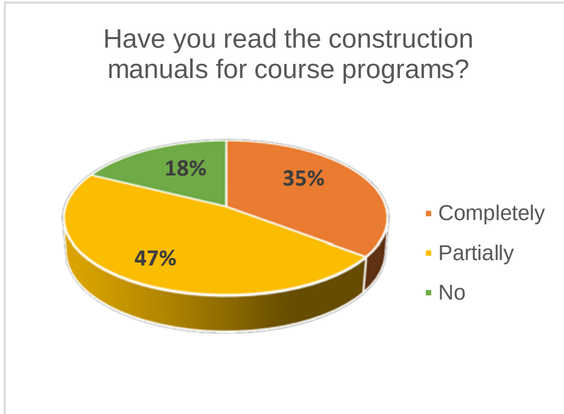

Figure 5.Question 1: Have you read the construction manuals for course programs?

The following two questions were focused on clearness in the process of implementation the course programs and the sections that it should contain. For the question if there was clarity in the process of creating the course programs, 44% of them are neither agreeable nor disagree; 25% consider that there was not enough clarity; 19% perceive the process as clear, while the remaining 12% show that there was nothing clear in this process (Figure 6 a). As, for the question, if there was clarity in the sections that the program should contain, 41% of the professors consider that, if there was clarity, 30% are not in agreement or disagree, the remaining 29% consider that there was no any clarity (Figure 7 b).

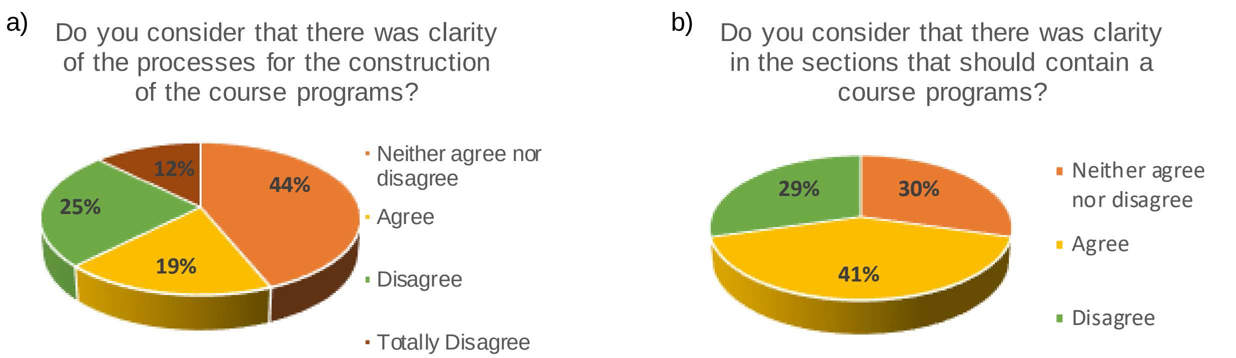

Figure 8. a) Question 2. Do you consider that there was clarity of the processes of the construction of the course programs? b) Question 3: Do you consider that there was clarity in the sections that should contain a course programs?

In addition, they are asked about the perception of the implementation process of the course programs. When asked about the efficiency of the process (Figure 7 b); 35% of professors consider the process as efficient while 65% consider it, inefficient or little efficient (Figure 7 a). To the question Do you consider that there were re-processes in the construction of the course program? 94% of the professors answered yes.

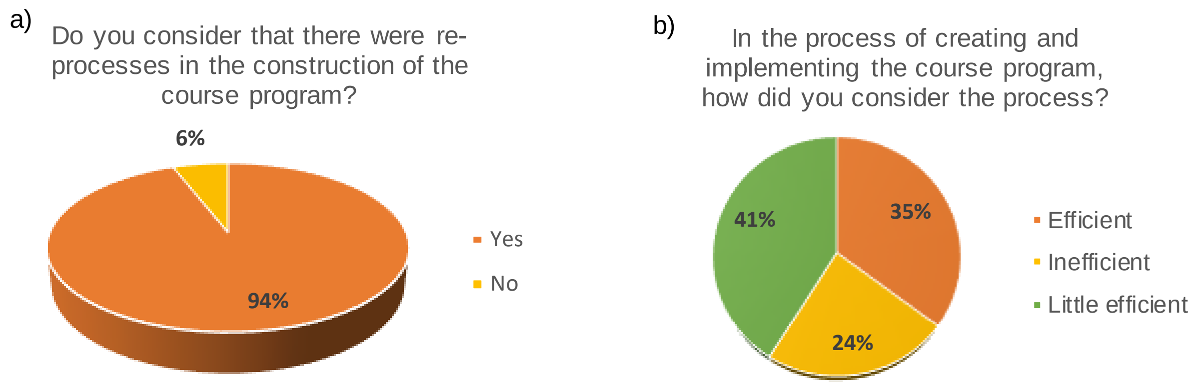

Figure 9.a) Question 4. Do you consider that there were re-processes in the construction of the course program? Question 5: In the process of creating and implementing the course program, how did you consider the process?

Within the evaluation process, it was also important to know whether the response time to the questions generated by faculty, during the implementation was appropriate and how much was that response time. Most teachers consider the response time to be appropriate (77%). 23% consider that this time was not appropriate (Figure 8 a). Response times are distributed as: a few hours (6%), one day (6%), between two days (47%), between one week (35%) and between a month and three months (6%) (Figure 8 b).

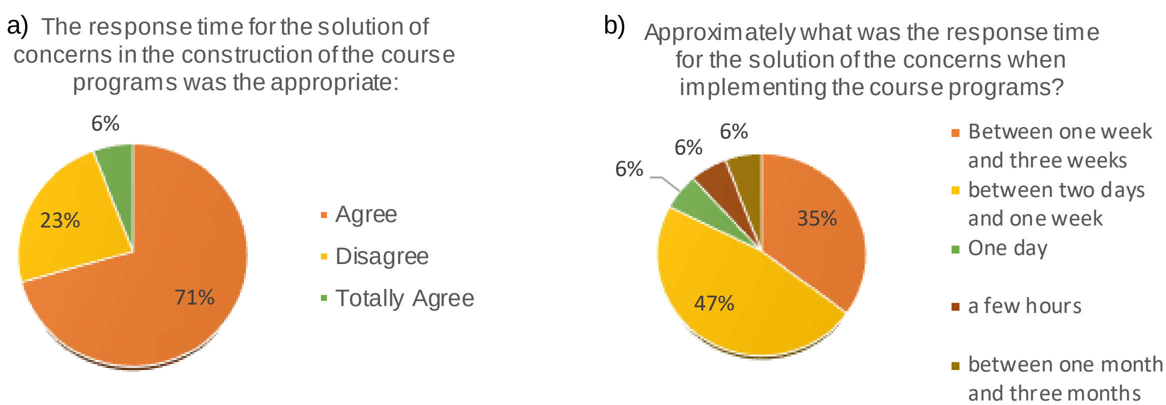

Figure 10. Question6: The response time for the solution of concerns in the construction of the course programs was the appropriate. b) Question 7: Approximately what was the response time for the solution of the concerns when implementing the course program?

We also evaluate which of the sections of the course programs are the most inconvenient to the professors. As can be seen in Figure 12, the section that most problematic section is “Outcome assessment rubric”; 10 of the 17 professors who conducted the survey think that. The learning outcomes and teaching goals section also generate some kind of difficulty.

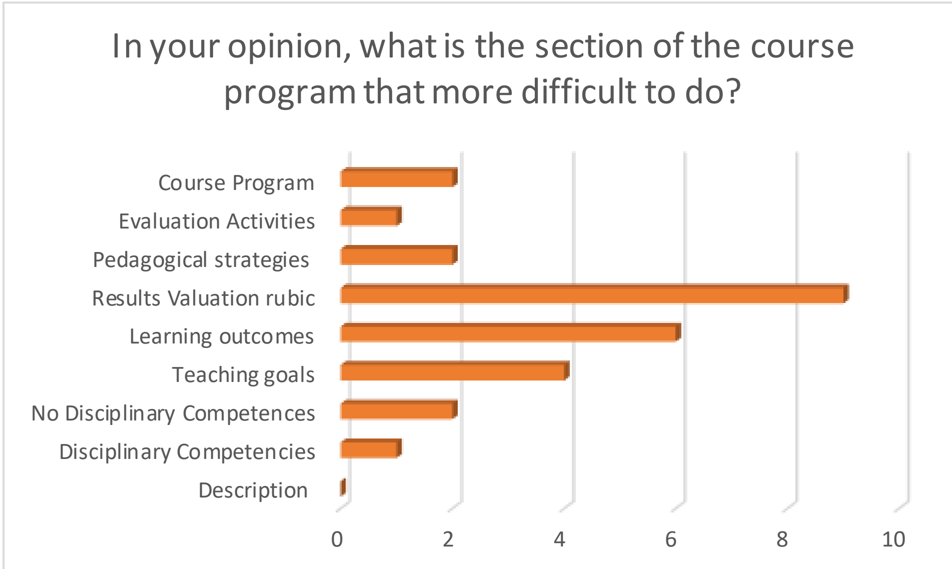

Figure 11. Question 8: in your opinion, what is the section of the course program that more difficult to do?

We made other questions to determine what were the strengths and weaknesses of the construction of the course programs under the philosophy of CDIO. We find that faculty believe that the greatest strengths of the process are: The generation of academic spaces to discuss relevant aspects of the program between professors, there was a previous work in front of the thematic contents of the subjects, the process was structured, it allowed to establish a homogeneous process generating course programs updated and homogeneity in the courses' subjects. As for the weaknesses observed in the process: lack of time, assignment of many tasks by the Electronics Department, the specific terms of each part of the course programs were a little confusing, too many sections and little clarity in process, content and lack of organization and planning.

PROPOSAL: IMPROVEMENT TO STANDARD 10.

Based on the experience of the construction and implementation of the course programs, we can identify a set of good practices in the design and implementation stages of a curricular reform under the perspective of the CDIO initiative. First of all, it is important to raise a structure of working groups that are responsible for disciplinary lines. These groups will be based on the integrity of the contents and their articulation with general skills to be developed gradually. During the implementation and even the operation and evaluation of the new program, these groups will be responsible for ensuring the articulation between lines, including training areas belonging to other schools. In particular, for engineering education, an example of these areas corresponds to sciences (physics and mathematics). At this point, we recommend to include in the work structure, groups responsible for the fundamental basic science lines. The work of these groups is to accompany School of Sciences, in the redesign of the courses and the integration of skills in them. A second element for the success of the implementation of a new CDIO program is the effectiveness and efficiency of the processes, mostly operational. At this point, it is of vital importance the traceability of meetings, agreements and decisions and the follow-up to the documentation. Then, it is necessary a methodology of project management that includes among others, control of changes and versions, schedules of activities and advance indicators. The management tools above allow saving time, knowing the progress of the process, avoiding the reprocesses and obtaining a program designed from high quality parameters.

The third element is associated with the paradigm of change management. In this sense, faculty and in general the actors involved in the reform of the program must understand the objective and the reason of it (define). The management group is responsible for motivating the commitment of faculty and keeping it informed of the progress of the curricular reform project (communicate and engage), translating the expectations of the reform in indicators of the day to day of each professor (detail) and to develop the implementation, operation and evaluation processes offering the necessary methodological and technological tools (training). On the other hand, it is essential for the process, to ensure the sustainability of the reform (assurance) and to seek the necessary alliances within the university to support the complexity associated with this process and mitigate the resistance to change. For the particular case of PUJ, we look for Learning, Teaching and Evaluation Center (CAE+E) and the academic Vice-presidency are aligned with the CDIO philosophy, in such a way that their offer of training of professors and accompaniment to curricular processes is by demand and based on the needs of the School of Engineering and its processes associated with the reforms. However, all the efforts of an engineering school that seeks continuous improvement, redefinition of its programs and that welcomes an innovative philosophy like the one proposed by the CDIO initiative, must have support from the structure of the institution (policies and investment). In this sense, the administrative management of resources (time, budget, internal services) and institutional processes must be efficient and effective in order not to hinder strategic reform projects and in general the culture of continually rethinking engineering education. Finally, we suggest that a curricular reform project should follow an operational model of implementation to avoid the overhead of work in faculty. Below, we describe an improvement to the standard 10 which includes the above elements.

Implementation proposal: Improvement to standard 10

Our proposal to improve standard 10, includes understanding the reality of faculty from the point of view of their daily functions, the additional activities inherent in the operation of a curricular reform and the design of detail of the program including the courses from a CDIO perspective. Figure (10).

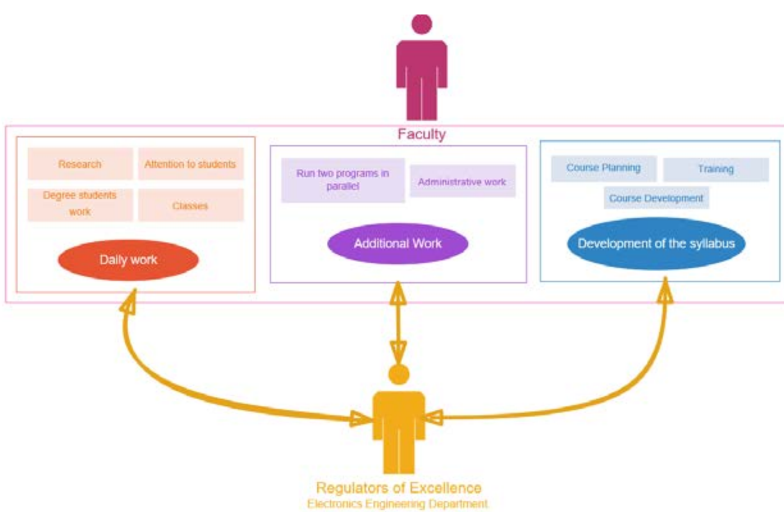

Figure 12. Faculty Work load

We will use the Business model canvas (BMC model) to summarize our proposal. The BMC model is a graphic representation of several variables that show the values of an organization

(Electronics Department). Usually, MBC model is used as a strategy tool for developing changes in a process (Electronics Program) or an organization (Electronics Department -Faculty). This tool includes the analyses of the state of the art of a situation of an existing process. BMC model defines nine categories as the building blocks of an organization or a process: Key partners, Key activities, Key resources, Value propositions, Customer relationships, Channels, Customer segments, Cost structure, Revenue streams.

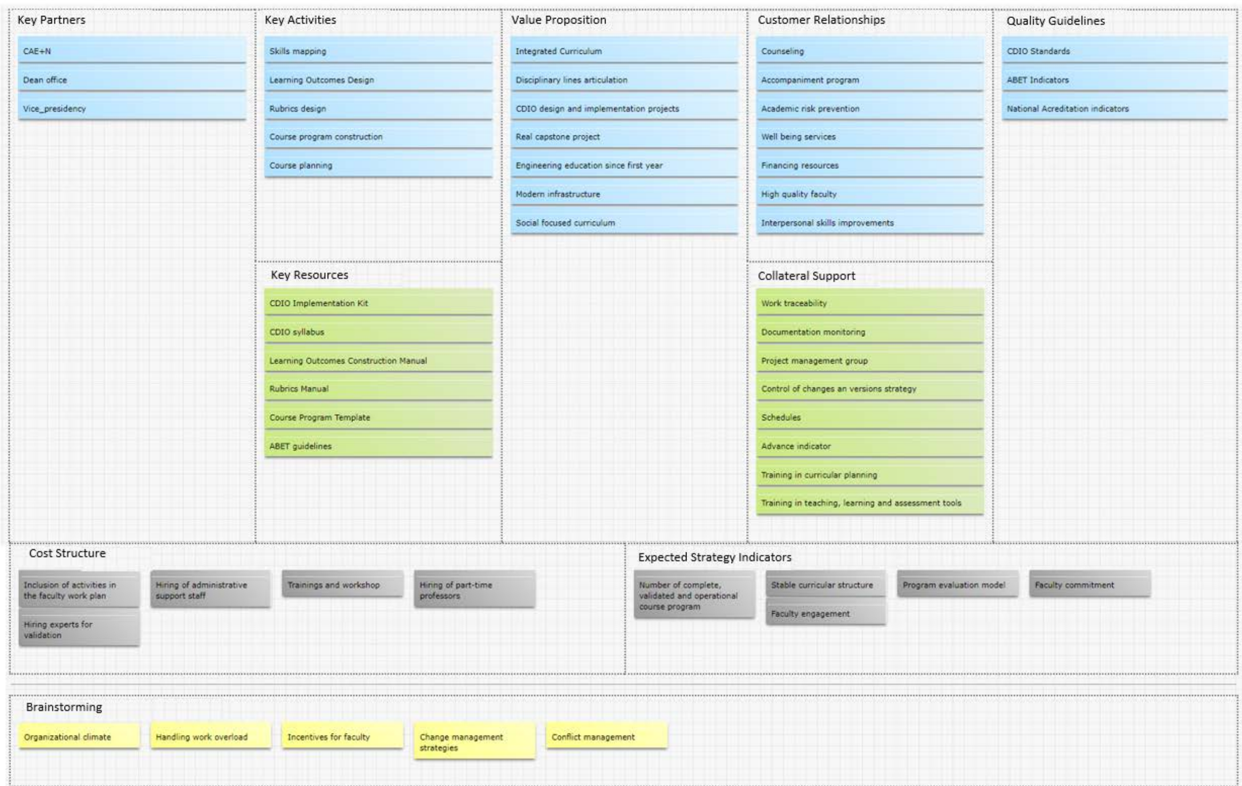

Figure 13. Business model canvas (BMC model) to summarize our proposal

We have adapted the BMC model for the case of a curricular reform and in this way, we have modified some categories to be consistent with an academic process. Then, we have replaced the Channels by Collateral Support, the Market Segments by Quality Guidelines and the Revenue Streams as the Expected Strategic Indicators. In addition, we include a brainstorming space to report some items that are not categorized in the BMC model categories. Figure 11 shows the resulting BMC as an initial proposal for the improvement of the CDIO standard 10.

CONCLUSIONS

This article showed the process used at the Pontificia Universidad Javeriana to implement the CDIO methodology and its challenges in the Electronics Engineering program. The most frequent challenges were overloading the work of the faculty and administrative staff by having two simultaneous study programs. This situation has generated resistance to change and situations of delay in the different activities related to the implementation.

Our work is oriented to articulate all the elements of each category of the BMC model to carry out efficient and effective improvement processes that do not resent the attitude of the faculty and instead can consider the reform as a project of professional growth.

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BIOGRAPHICAL INFORMATION

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