ACTIVE LEARNING AND CDIO IMPLEMENTATION IN COLOMBIA

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ABSTRACT

In this paper we discuss common problems in Colombian universities in regard to engineering professional programs. We also discuss the reasons to implement a curriculum reform following the CDIO model at Icesi University, and present some preliminary results of implementing this reform, mainly concerning student motivation and attrition reduction.

The adoption of CDIO model is aimed not only to offer a integral engineering education, increase the quality of our programs, establishing a cycle of continuous improvement and also to encourage students by offering a challenging curriculum that focuses its professional component on solving engineering problems.

We present the educational project of Icesi University that involves the use of active learning in all courses. This has paved the way for implementing the CDIO standard. Class space becomes a space for learning using strategies based on problem-based, discussions and case studies where our students solve engineering problems by conceiving, designing and implementing solutions to these problems.

The results of the whole learning process that we have implemented are evidenced in the value added to the students. The average performance of our students is measured by the state exam conducted by the ministry of education and the professional practice evaluation. The average of these two test our students are in the 90th percentile and we receive the freshmen in a very lower rank measured for a similar test realized at the end of the secondary school.

KEYWORDS

Active Learning, Curriculum Design, CDIO standard, Computer Engineering, Computer and Communications Engineering.

INTRODUCTION

Icesi University is a small, private, and nonprofit university founded in 1979 by top business leaders from the region of Valle del Cauca (Cauca Valley), in the southwest of Colombia. Valle del Cauca represents the third most important economy of the country, which is constituted by the largest multinational corporations, as well as the pharmaceutical industry, important software companies and the most representative service enterprises of the country. Valle del Cauca also has a remarkable agricultural potential that is mainly based on the production of sugar cane and biofuel. 90% of the sugar cane produced in Colombia, and 100% of the Bioethanol consumed in the country is supplied by this region.[1]

Icesi University is now composed of five colleges and 19 professional programs. However, for a long time, and since its foundation, it had only two careers, Business Administration and Systems Engineering (also called Computer Engineering). In the last 10 years the university opened several engineering programs, in particular, Computer and Communication Engineering and Industrial Engineering.

The programs of the Faculty of Engineering have duration of five years. All of them are recognized by the outstanding results obtained in their external evaluations. In particular, the "Saber Pro" evaluation, applied by the Ministry of Education to all students near graduation, for which all of our students are in the 90th percentile[2]. Similarly, the professional practice of our students is evaluated as outstanding by employers. 90% of our newly graduates obtain the highest ranking in their professional evaluation[3].

All three engineering programs hold the national high quality accreditation, which is issued by the Colombian Ministry of Education through the National Accreditation Council (CNA). This council issues a voluntary high quality accreditation [11].

Two of the three programs, Systems Engineering and Computer and Communication Engineering, have begun the implementation of their curriculum reform following the CDIO standards. In the third program, Industrial Engineering, the reform will be implemented in 2013.

For over 15 years the University has based its educational model on active learning [4]. We define active learning as a strong involvement of the students in their own learning process. This definition is similar to the active learning definition used in other educational papers [14]. In contrast to traditional learning models, active learning demands from professors further time, effort and reflection, not only for preparing the teaching materials but also the activities to be done at the classroom, as well as for reflecting on the results afterwards [4].

MOTIVATION

The low student enrollment in engineering programs that requires a strong background in math and science is an evil that afflicts many countries in the western world and is a special phenomenon in Latin America. This phenomenon has been comprehensively analyzed by several authors such as Oppenheimer [5]. This low demand for engineering careers is caused, among others, by cultural problems and the inadequate preparation of students in secondary education (K-12) in areas related to science, technology, engineering and mathematics (STEM). According to our analysis, among cases of these problem are the cultural appreciation of engineering professional programs and the low social appreciation of teachers [5].

The results of the PISA Test (Programme for International Student Assessment) conducted by the OECD (Organisation for Economic Co-operation and Development) show that Latin American (LA) countries are below the average with respect to other OECD countries. Even though in recent years Colombia has improved its overall results in the PISA Test, its results in

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[1] In Colombia, all the automotive gasoline uses between 7% and 15% of Ethanol.

[2] In the last test the average of our students was 1,5 std over the national average. We obtained similar results in the last 2 or 3 years.

[3] This is an internal assessment completed by the employers of our students.

math and science are the areas with the lowest assessment in LA [12]. To counteract this drawback, a recent World Bank mission in charge of conducting an education study in Colombia recommended adding one year of schooling, from 11 to 12 years, to compensate in some way the low results [13].

This low preparation leads to high failure rates in related courses thus causing a widespread perception that engineering-related areas are particularly difficult. The perceived difficulty, together with high dropout rates, causes among students a general sense of fear about engineering professional programs thus affecting their enrollment levels.

Contrary to this enrollment deficit, our graduates are highly demanded by industry. Wages earned by graduates are the highest in the sector. Moreover, the employment rate of graduates in the first year is over 95% [7]. It is curious to note the apparent contradiction between the high demand for professionals in engineering programs and the low enrollment to these programs. This is the reality in most LA countries.

Facing the problem of poor preparation of freshman, many universities have a tendency to either lower their quality standards or reducing to a minimum level the training in math and science. In some cases, some programs are advertised using the slogan "Study Engineering WITHOUT Mathematics."

Icesi University has chosen not to reduce standards in math and science requirements and proceed in a process of curriculum reform that encourages students to pursue engineering careers. This strategy emphasizes the usefulness of mathematics and science for professional life, and focuses on a reform of the professional courses that constitute the core of our engineering professional programs.

CASE STUDIES

The educational project of Icesi University involves the use of active learning in all courses. This has paved the way for implementing the CDIO standard. Class space becomes a space for learning using strategies based on problem-based discussions and case studies where our students solve engineering problems by conceiving, designing and implementing solutions to these problems. Our curricular reform has focused primarily on defining outcomes---competencies of students and their close relationship with curriculum, and most importantly, on evaluating the acquisition of these skills throughout the career. This assessment is an innovative strategy in Colombia and Icesi University was one of the first institutions in implementing it.

We embraced the CDIO initiative and followed the syllabus version 2.0 that defines the knowledge, skills, objectives and corresponding proficiency levels [2]. We compared this model with the requirements of the Ministry of Education of Colombia, relevant professional associations (i.e., IEEE, ACM, ACOFI[4]). With these elements and to select and prioritize the desired professional outcomes and their corresponding proficiency levels, we conducted a survey that involved stakeholders, students, alumni, and faculty members. For this, we followed the recommendations and procedures defined in the CDIO literature [1], [3] and [15].

For each professional cycle, basic cycle and engineering cycle, we defined the learning objectives that correspond to the competencies identified for each program. We have defined a series of related courses that constitute the professional areas of each professional program. Each area has a capstone course at the end of the group (cf. Figure 1). The students' outcomes, in terms of both our educational project and the desired professional skills, are evaluated in a compulsory professional practice. We do not have yet the complete assessment results of

[4] Colombian Association of Engineering Faculties

students who have passed their training under the new curriculum. However, we have completed an initial assessment of a training group consisting of a sequence of three courses of the Algorithms and Languages area. These courses are taught from first semester and are considered by students, together with mathematics, as the most difficult subjects of the program. They had the largest rate of failures in Computer Engineering and Computer and Communication Engineering careers. The results are promising. We increased the demand for these courses by focusing on problem solving. Previously, the emphasis was on the semantics and syntax of programming languages. Now the emphasis is on solving problems using computational thinking [8], [9]. With this new method this sequence of courses has begun to transform. The GPA has increased by 5% (0.25 points on a scale of 5). The failure rate fell by 5%, the percentage of cancellations of these courses has fallen by 3%, the same as the standard deviation of the assessments. The dropout rate has fallen race between 5 and 7%.

INNOVATION IN TEACHING AND LEARNING

We are implementing a curriculum reform in two programs of Engineering, Computer Engineering and Computer and Communications Engineering, the basic structure of building blocks of the two programs is shown in Figure 1.

We show a very similar basic cycle of fundamental courses in Mathematics and Science subjects and a block of administrative, economic, liberal arts, humanities and entrepreneurship. We also have a cycle of basic engineering courses that have some similarities among them but differ in some areas of math and science. Finally, the professional cycle is different for the two careers. Both have two professional area particular to each program, which we call professional emphases. In the case of Computer Engineering (IS) these areas are Information Systems and Software Engineering. In the case of Computer and Communications Engineering (IT), the two professional emphases are Infrastructure and Services. Electives are different for each career and in each of the professional emphasis.

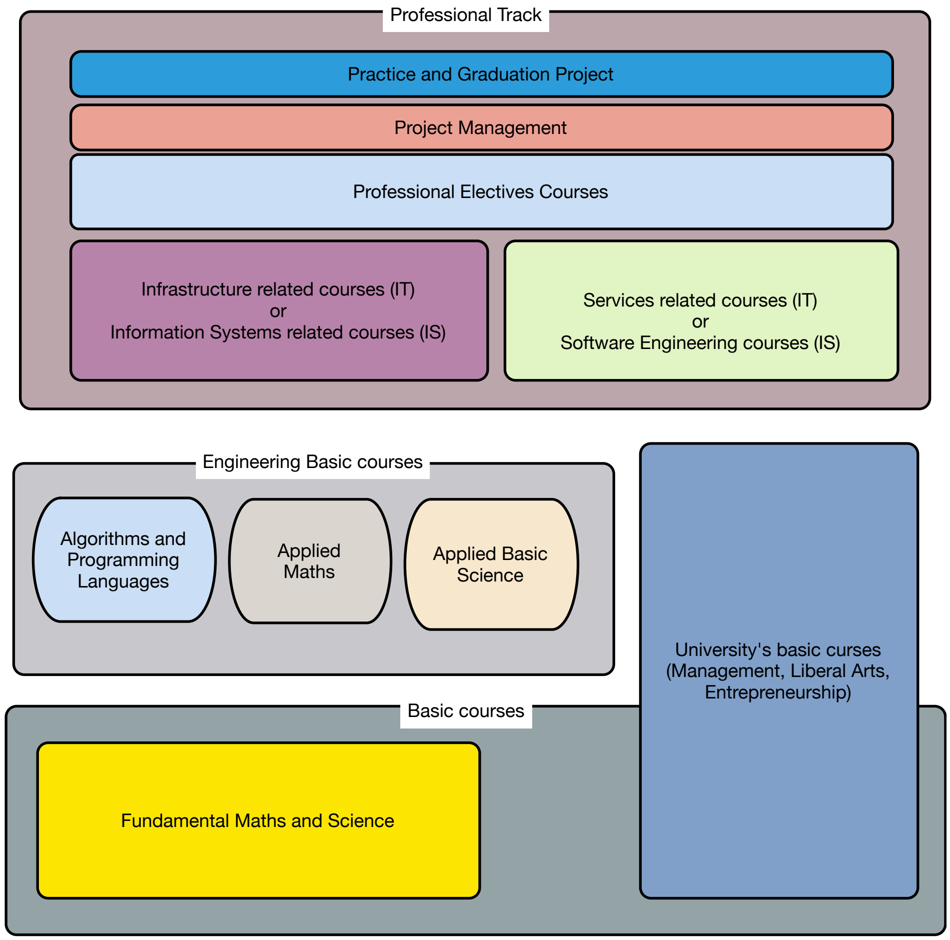

Figure 1 - Curricular structure building blocks

Active Learning

Active learning practices are not common in Colombian universities. This implies a change in the mindset of teachers since their role in the classroom is different than in traditional learning models.

In active learning the teaching process is transformed from a lecture-based model to a class rich in activities that promote learning and critical thinking [14] [16] [17] [18]. Most university professors are not trained in teaching, they have a professional career on engineering and postgraduate studies at the Masters and PhD levels. Very few teachers have had educational training during their career and try to play in the same way as their teachers taught.

Active learning poses new challenges. The teacher's role is to guide the learning process of the students, not only to develop themes and deliver the contents [4]. The classroom is no longer a place where the teacher imparts knowledge and the students takes it, the classroom is a place for discuss, learn and assimilate the knowledge with the help and experience of the teacher. Change form a place of instruction to a learning site [4] [14].

This new way of learning must also change the mindset of students who should not get to the classroom only with the goal of listening to the teacher's speech. They must come to answer questions, exchange ideas, discuss these ideas and develop new ones. This is the dynamic of active learning in theory. In practice these legacy tradition of the teacher-student relationship are hard to change. The teachers, some of them are giving lectures and students wanting to receive this type of class, then spent years in school receiving an instruction in a vertical way.

As a story we can tell that a parent came to ask if it was mandatory for her son to take extra math classes to approve the courses in the University, when must be clear for all students that no extra course should be required.
We discovered that a private teacher of math, external to the university, offered classes at extra cost with very good success among the students, he had almost established a parallel university. We inquired the topics in those classes and found the same topics than in our regular courses including the same type of material but in the form of lectures. Having identified the problem of rejection or fear by students to cope alone with new themes under our active learning methodology, we changed the dynamics of these first mathematic courses. All the new topics to be covered in the next class are now introduced in lecture form by the teacher in the previous class. With this simple adjustment the cancellation rate decreased by 20% and the success rate in these courses improve.

Active learning involves intensive interaction and participation in class and is best realized in small groups, where the teacher can maintain a strong interaction with the students. Also a physical structure can help, small classes are ideal to have a strong interaction. At Icesi University classrooms have a maximum capacity of 35 students and the university-wide average of students per classroom is 21.8. When courses require labs, these are limited to 24 students. We are testing others methodologies like peer to peer learning well adapted to bigger groups [19], but all the university classrooms were built thinking in small groups.
The class attendance is mandatory. A student fails a subject by missing more than 20% of the classes. The reason behind this principle is that active learning is based on a strong interaction in the classroom, group learning, and classroom discussion that cannot be doing if the student does not attend.
An experienced teacher revises this methodology, results and learning processes based on evaluations inside and out the classroom, the feedback from students and independent evaluations carried out by the faculty.
To introduce active learning to new teachers we have a training process. New students are also introduced to the university's active learning methodology at the beginning of the program.

In all the courses of the curriculum the laboratory practice is integrated with theory. The course is a unit and the practice is an integral part of them. Many of these courses propose projects that integrate knowledge and skills from learnt in the corresponding course and other courses taken previously or simultaneously by the students.

Projects and capstone courses

Introduction to Engineering

In all our engineering programs we have implemented an introductory course to engineering. The aim is to introduce the student important aspects of what will be their professional future, and show them how to solve problems by applying engineering methods and techniques. This course divides a problem into several phases with the goal of conceiving and analyzing multiple solution alternatives, as well as implement and think about the operation of the selected solution. These phases correspond to the foundations of the CDIO framework [1]. Each program has a special emphasis on problem solving. For example in the area of information technology, the emphasis is on algorithmic thinking.

Capstone courses

One of the objectives of the curriculum reform has been to introduce some aspects of curricula integration. We created new capstone courses that integrate skills among courses. We have defined at least one capstone course for every professional area. Computer Engineering and Computer and Communications Engineering have two capstone courses each. In Industrial Engineering we plan to have two or three capstone courses.

Graduation Project

At the end of their professional program students must complete a graduation project in a time of at least two semesters and six (6) academic credits. This project plays the role of a capstone project that applies many skills developed in the career, not only technical skills but also project management, teamwork, leadership, critical thinking, and communication skills. The project must be defended in front of members of the faculty and often with outside experts.

Integration with Industry

We have begun to integrate into standard courses projects with companies of the region. This is realized through either projects in capstone courses, or graduation projects. One of these companies is Carvajal Technology and Services[5], the largest company of technological services in Colombia, and one of the top five in LA Carvajal built a special laboratory within the university to be used for these projects conducted by our students with the supervision of our Faculty together with engineers of the company. This initiative was launched in January 2013 and the first projects will be implemented this semester.

Professional Practice

Within the training plan, the University also has a mandatory semester Internship. During this semester students go full time to the company to work on projects and specific areas. Companies should appoint a tutor for the student and the University makes an advisor who oversees and directs the activities of students in their first professional job. If the student requires any technical aid, he or she can come to the University to resolve any guidance. The practice lasts at least four months and is evaluated by both the company and the student. The evaluation criteria focus mainly on generic skills such as critical thinking, teamwork, leadership, problem solving and professional technical skills.

Our goal is to obtain on average, 90% of students qualified as excellent (maximum level) and very good (second position). The performance of the students enrolled in the programs of the Faculty of Engineering exceed this goal, 95% of our students are scored in this range [7].

In some cases 15 or 20% of the students want to use this semester to create a technological entrepreneurship. The University encourages this entrepreneurship. In these cases, the university provides them with a special training in business modeling, help to build a marketing plan and provides special workspaces for this task. All beyond the entrepreneurship themes delivered as part of the curriculum. This work replaces professional practice.

We apply a comprehensive assessment to all our students before graduation with the goal of knowing their feedback about their experience at the University. This assessment is conducted

[5] http://www.carvajaltecnologiayservicios.com

before the degree and after completing the semester of professional practice. We conduct this survey covering all aspects including academic, administrative, and learning. Then we held a group meeting, which discusses the survey's findings. Every year we find that the competence that is appreciated the most by students is the skill to learn continuously, also known as long live learning. This is of course a consequence of the active learning process. Skills in problem solving, and the ability to find innovative solutions are also highly appreciated. These competences are the result of having our students highly involved in in a participative learning process. These are similar finding that mentioned in the literature [14].

SKILLS ASSESSMENT AND LEARNING OBJECTIVES

In all the professional courses of our engineering programs we have defined learning objectives aligned to the exit competencies and the specific course outcomes [1][3].

Each course must have the academic topics corresponding with the disciplinary knowledge described in the CDIO Syllabus section 1 (Disciplinary Knowledge and Reasoning), which has been tailored following the program definition. Also they must contain the outcomes corresponding to CDIO section 2 (Personal and Professional Skills and Attributes), section 3 (Interpersonal Skills: Teamwork and Communication) and section 4 (Conceiving Designing Implementing and Operating Systems).

The professors in charge of each course must define and specify the corresponding learning activities oriented to reach the learning objectives defined for the course. These activities are discussed and evaluated together with the academic leader in the particular area, and with the teaching and learning support office. The evaluation criteria and specific rubric to assess these outcomes [1][3] follow a similar process. This part is mandatory for the professors in all professional courses.

To register for this process, we define a special format where all the parties are involved. This form must be completed by the instructor of the course and approved by the academic department head. We are currently implementing this process in all our professional courses.

FIRST JOB EVALUATON

One weakness of our system is the lack of evaluation of the professional performance of our alumni beyond their first year of graduation. We are interested in measuring these aspects 3 and 5 years after the completion of their undergraduate program. Currently, the University follows the alumni during their first graduation year as part of the professional training program. We have conducted activities to monitor the professional life of our graduates in the years following the first year of graduation. However, this effort is not yet systematic. We have implemented a serious and well recognized program that monitors and supports our graduates during their first professional year.

The results of this program are highly positive, employability is higher than 95%, and only 5% of our graduates reported that they have left their jobs to look for better conditions or pursue a graduate program [7]. Fortunately, In Colombia, and in part due to the shortage of Engineers, the levels of employability are remarkably high for engineers graduated from reputable universities such as Icesi University.

CONCLUSIONS

In this paper we presented the experience and partial results of a curricular reform experience that was applied to two professional programs in the field of information technology and communications. This reform has been possible because of the commitment of Icesi University

to continuously improve our educational model, which relies on a long tradition of active learning.
This has paved the process of adopting a new curriculum model that is focused not only on technical knowledge, but also on professional skills demanded by industry and society.

Considerable effort has been necessary to change the mindset of, and to understand this new model by our students and faculty. Nevertheless, the small size of our University and the Faculty of Engineering, as well as our efficient processes focused on industrial practices borrowed from the private sector have facilitated the process.
We encourage all faculty members to improve skills on assess learning objectives, other than the personal discipline. We are conducting a process of training and building assessment rubrics. We are now evaluating and improving the skills assessment rubrics to close the cycle of continuous improvement in the curriculum.
We are implementing the revision of the entire process, course by course, including how learning objectives are defined and evaluated, and how the teaching and learning activities are carried out in the classroom accordingly, they are part of the continuous improvement process we are conducting.
Finally, the institutional commitment is crucial to continue implementation of the CDIO model. In particular, to improve the laboratory infrastructure required to develop capstone courses and best integrate the objectives proposed by the CDO framework. This is our goal in the near future.

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