Paper 2. Experience in a first year introductory course of a methodology based on projects in the engineering faculty

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Abstract

Nine programs comprise the engineering faculty of National University of Colombia. During the first semester each program offers an introductory course that even though it is different for each discipline, shares some common elements around an interdisciplinary methodology denominated COMFIE. Professionals from psychology and engineering have developed this methodology in the faculty, which fundamental feature is the simultaneous inclusion of academic contents, the student formative process, the support during the adaptation to the university life and the recognition of the engineering social and environmental responsibility.

COMFIE methodology consists in a set of activities that privilege the classroom learning complemented with a parallel counselling and the development of competences. The mentioned methodology is included by professors by means of a project that should be developed during the semester and it is intended to achieve objectives proposed for each program.

As a mechanism for strengthening the educational process, at the end of the term an exercise denoted as: "Journey for presenting first semester engineering student projects" is performed. In this meeting, students present their project results using a poster. The main purpose of this session is to generate a space for student interaction and learning about the different approaches of the faculty. The skills worked out with the development of the project and the final presentation have contributed to participants feeling more confident and aware of the role of engineers in society.

1 Introduction

Numerous universities have recognized the importance of educating engineers who possess not only technical knowledge but also social and innovation abilities. Current engineering program graduates have to face work environments based on complex systems where it is essential to have knowledge and skills that promote productivity and entrepreneurship (Crawley *et al.,* 2007). This approach to competence development seeks not only to create competent professionals but to educate citizens that are actively aware of their environment and of global concerns (Gonzalez & Wagenaar, 2009).

Many initiatives around the world have sought to develop skills as a part of the curriculum. For instance, the project *Tuning Educational Structures in Europe* (Gonzalez, 2003) that defines directives for curriculum design based on competences or *The Partnership for 21st Century Skills* (P21, 2009). Another approach to educate engineers is the CDIO (Crawley *et al.,* 2007). In the same way, several methodologies have been proposed to develop these competences; one of them is the project-based learning (PBL).

Project based learning initiates with the assignment of a set of tasks that finish with a product, usually a written report or an oral presentation. PBL is an effective methodology for developing skills, since a

project may involve a wide spectrum of problems that can be defined by instructors or students forcing the latter to design and probably implement the solutions as they work as teams (Prince & Felder, 2006). Compared to the students that follow a traditional learning approach, those that participate in projects show a higher motivation, better abilities for team work and communication, as well as a deeper understanding of the issues related to the professional activities (Prince & Felder, 2006). Even some institutions have designed curricula based exclusively on projects (Ulseth *et al.*, 2011).

At the School of Engineering at the National University of Colombia, an interdisciplinary group that includes professionals from psychology and several engineering programs and has been working on an initiative that we call *COMFIE*. It started with the recognition that the demands of professional life of today's engineers were not being taught in our classes. It was, then, necessary to articulate the teaching of traditional topics of engineering with the development of competences in the classroom by means of their incorporation into the expected outcomes of our programs. The mechanism adopted for including the new required skills into the curriculum was through a project based learning methodology. This is now part of an Introduction to Engineering course being taught during the first semester of all programs in our school.

This paper describes the development of the methodology, its implementation and some of the results obtained to this day.

2 Background

The National University of Colombia is the largest state-run university of the country. It has a population of over 40000 undergraduate students and 8600 graduate students in four main campus locations. The school of Engineering at the Bogota campus is the largest school with more than 6000 students in nine undergraduate programs. The admission process is a highly competitive one that includes a national exam where, for the school of Engineering, only one out of every 14 candidates is admitted. The admission exam scores in Engineering are, almost invariably, the highest of all schools. Thus, the student population is expected to perform well in all programs. On the other hand, the exam score is the only criterion for admission. Therefore, first year student populations can be quite heterogeneous.

The student body is composed mainly of low to middle income students. Every cohort includes about 800 students and about 15% of the new students are female. Because of the national education system organization, a new cohort is admitted twice a year. Although most of the new students are 17 to 19 years old, almost every period, very young students are admitted. At the same time, some students older than 25 years old are often admitted. However, there are other variables such as socioeconomic conditions, previous studies or parents' education that should be taken into account in methodologies and curricula. With the purpose of introducing skills and considering the particular features of the first year population, some modifications were adopted in the programs of the school of engineering.

As part of a curriculum reform, performed in 2009, a methodology was designed to respond to the interests of the stakeholders. It was decided that the curriculum to be implemented should respond to the interests of society as a whole, as well as to the interests of employers, the program students, the university and the faculty. It was also deemed necessary that curricula be adaptable to changes in technology and the environment. This could guarantee the continuity and permanence of our programs without the need to implement major reforms very frequently. The first step for ensuring that the interests of stakeholders could be taken into account was to do a diagnostic. Three surveys were taken involving students, program graduates and faculty.

Program graduates' survey: A survey taken by Dechema (WCEC, 2004) among chemical engineers around the world was adapted to our needs and applied to graduates from our electrical and electronics engineering programs. Its purpose was to identify the strengths and weaknesses of their education process at the university. A set of skills and competences was presented to participants and they were asked to estimate how important each of those competences had been during their college life and their professional careers. A "gap" was computed as the difference between the requirements of professional life and what their education provided. Positive values mean that they received more that they have needed while negative values imply that a competence has been more important than could be expected from their college experience (DIEE, 2007).

The set of competences includes some "academic" ones like the ability to apply math or science. But most skills were the more professional or social ones like ethical and professional responsibility, sustainable development awareness, team work and project development abilities. All competences had a negative gap, with the exception of the knowledge type ones. This result coincides with the results of the original chemical engineering results in 62 countries. The results, apparently true on a global school is that college education has been mainly directed at developing technical and scientific abilities while providing few opportunities to develop all other skills (WCEC, 2004).

Student survey: Based on the study by Eris, *et al.* (2007), "Persistence in Engineering (PIE) survey" an adaptation was made, authorized by the author of items 2a, 2c, 3b, 7 and 13b of the PIE and a questionnaire was created and applied to first year students during their first semester. The questionnaire includes 25 questions. Additionally determining the competences in which students feel less proficient, they were asked about the considerations they made while deciding to major in engineering. The competences more often cited were difficulties in oral communication, perception of lack of self-efficacy, difficulty in joining a group and inadequate teamwork performance.

Longitudinal study: In addition to the surveys, a longitudinal study was developed in which the process of adapting to college life was analyzed. Results of this study have been presented elsewhere (Acuna *et al.*, 2011), however, the main result of this study was the proposal of a methodology described herein. This was the result of a previous diagnostic where the development of professional and social abilities was gradually incorporated into the syllabus of an introduction to engineering course that students have to take during their first semester.

3 Description of the methodology

The process of developing a methodology (which we call COMFIE) was a joint effort by professionals of Psychology and Engineering. The methodology being proposed is developed along three action lines: classroom activities; classroom-parallel activities and extension activities. The conditions for establishing this set of activities have been:

1) A common feature for all engineering programs at our school is the *Introduction to Engineering* course during the first semester.
2) The contents of each course are developed jointly with the introduction of the methodology.
3) The methodology is incorporated into the development of course projects.

A brief description of each of the action lines follows:

1. Classroom activities
   This is the central space where projects are developed. The main competences being developed here are Teamwork, Oral communication skills and Interdisciplinary work. These

skills are used as a support for the reinforcement of the adaptive process. During the course of several classes teams of students assess their performance, considering their progress, their capacity to work with others, their disposition and attitude, among some other aspects. To this end, immediate feedback is provided during oral presentations by students about the project progress.

2. Classroom-parallel activities
   This line of action complements the classroom activities to reinforce the competences being developed. Students may request a consult with the psychologist and they may participate in individual or group advisory or tutorial sessions.

3. Extension activities
   Comprise all the actions aimed at reinforcing the effects of the formal activities. A talk is given to new students' parents, invited to attend some of the induction activities. In addition, seminars are given on a regular basis to the faculty of various departments.

3.1 Classroom activities

Since the purpose of this paper is to present the development of student projects, an activity belonging to the first line of action, some details of that line will be presented herein.

The objectives of the Introduction to Engineering courses are to introduce the student to the field in which they will major, to the language and concepts that underlie that field. In addition they are exposed to the main issues associated to the environmental, ethical and social responsibilities inherent to engineering works. During their classroom experience students should face social and environmental problems related to their work in engineering projects. They also work on projects focused on the solution to local, regional and national level needs. It is expected that they learn from experiences from around the world. The projects also provide opportunities to interact with professionals from different disciplines.

The projects developed thus far in all programs have been focused on health, transportation, environment, energy, alimentary security among other topics. However the most frequent topics vary from one program to another. In chemical engineering, for instance, the most popular topic has been mining and pollution; in civil engineering projects related to erosion and soil conservation, road construction have been frequent, etc.

During the development of the projects there are several moments where feedback is provided by the team of psychologist and engineering faculty. These feedback sessions are scheduled at the beginning of the project, at some point during the development and at the end. The psychologist, on one hand provides feedback about the students' observed behavior both at the individual as well as group level. The faculty, on the other hand, provides a more frequent guidance on the technical aspects and monitor the progress of the work. At the end of the project a formal session is designed to allow the public presentation and evaluation of the projects' results. A formal feedback session is then conducted to help students reflect on the experience and try to learn from it.

3.2 Case study: Projects in electronic engineering

The exercise performed in the first semester courses is illustrated through the projects carried out in the electronic engineering program. Work teams comprised between four and six randomly selected students propose a project for designing a technological device that should be marketed and based on

electronics fundamentals. At the end of the term, students have written a document that contains: the technical, human resources, marketing and business plan as well as the impact analysis of the technological solution. Many projects refer directly to environmental and social issues such as: a system for preventing forest fires, irrigation systems that use alternative energy sources, a localization and tracking system for underground mining and a system for controlling home energy consumption. It is important to mention that students do not build the proposed products.

Proposals are constructed in four stages: necessity definition, technological research, solution design and solution presentation and defence.

Each stage of the project development includes written reports and oral presentations. In these reports, the content, methodology and results are reviewed as well as ethical aspects that include intellectual property issues. These partial tasks allow the monitoring of students' projects and the experience of working in teams.

3.3 The "journey"

A mechanism was designed to strengthen the process and to provide a closure to the semester activities in the courses. It is called "Journey for the presentation of projects". The main purpose of this session is to generate a space for student interaction and learning about the different approaches of the faculty.

Preparation for this journey starts at the moment the group of students selects a topic to be developed during the semester. And the preparation continues with each feedback session. After the students present their projects to their peers and receive the final feedback, each course section selects a few groups that will represent them in the "journey".

The journey is basically, a poster section in a simulated engineering conference. Prizes are awarded to the best posters and some other categories. The event is open to the public and faculty and students are invited. It has gained some popularity.

Another aspect that constitutes a challenge to the students is the role that they play in the evaluation of the projects in order to determine the best ones. We emphasize that students recognize the importance of working with peers, of being able to recognize the work of others. Therefore, nine students are selected and they are given some guides that include criteria such as creativity, social and environmental impact, team work, poster quality and oral presentation. They are the judges in that selection.

4 Results

The methodology has had an impact in all programs of engineering. It originated in one program and has been adopted by all nine engineering programs. This, very often required the selection of faculty that was committed to the use of the methodology and to the development of the selected skills during the course. Currently, the faculty in charge of the Introduction to Engineering courses are some of the most dedicated and experienced in each program. Accordingly, the student assessment at the end of the term has risen steadily since the methodology was adopted, which reflects some level of satisfaction among the students.

Since the "Introduction to Engineering" and the "Engineering and Sustainable Development" courses constitute the axis for the implementation of the COMFIE methodology, a survey was designed to

establish what students perceive as its most important aspects. Students were asked what they thought were the main contributions of both the course and the methodology to the student's education. This survey was applied to 329 students of engineering who had attended all COMFIE sessions. A summary of the survey's results follows.

In the first place students were asked whether the "Introduction to Engineering" had somehow changed their perception about their chosen major, 69% of respondents answered YES. Curiously, it was found that most of those responding NO have some family member or relative in an engineering related field. Similarly, those responding YES said that they now perceive engineering as an interdisciplinary profession that contributes to social problems.

Furthermore, students were asked about the contribution of the project work or of the topic of their work in the "Introduction to Engineering" or the "Engineering and Sustainable Development" courses. They were presented with nine options from where they were asked to choose up to three. The available options were: a. Recognition of the impact of engineering on society; b. Social responsibility of engineers; c. Professional ethics; d. Team work; e. Interdisciplinary work; f. Oral and written communication; g. Environmental impact of engineering-derived products; h. Global perspectives of engineering; i. Technical engineering knowledge (See figure 1).

A similar question was asked about the perceived outcomes from the COMFIE program. The question included all items mentioned before except the one on engineering technical knowledge (item i.) this one was replaced by the adaptation to college life. The results, shown in figure 1, reflect this fact.

The results of the survey show that students feel that they have strengthened their team work skills and their oral and written communication abilities both in the project work as well as a result of the COMFIE program. An important result of the program has been the students' awareness of the need to work in interdisciplinary teams for the solution of engineering problems. Recognition of the potential impacts of engineering projects on society and the social responsibility of engineers was also chosen by the students. We hope that this new perspective on engineering may provide them with a broader viewpoint of their professional work and to understand its impact on sustainability. One remarkable result in our survey was the low priority given by students of the strengthening of their perception of environmental impact of their projects. Only 14% of the respondents considered that this aspect was relevant (See Figure 1). As a result, it has been agreed that this aspect should be emphasized for the following cohorts.

Thanks to the Introduction to Engineering course, first year students consider that they have widened their vision of engineering and its expected fields of application. They also emphasize the interaction of their work with other disciplines. The prevailing point of view after taking the course is the characterization of engineering as a profession that seeks to improve the quality of people's lives.

The project defense sessions and the poster journey have allowed observing students' and professors' perception about the expected skills worked during the exercise. From the forms utilized by students that act as evaluators in the journey, we summarize some of the opinions that freshmen express when they are asked about their experience working in projects as teams.

"Working in projects means: "opportunity", "motivation", "gratification" towards the career."

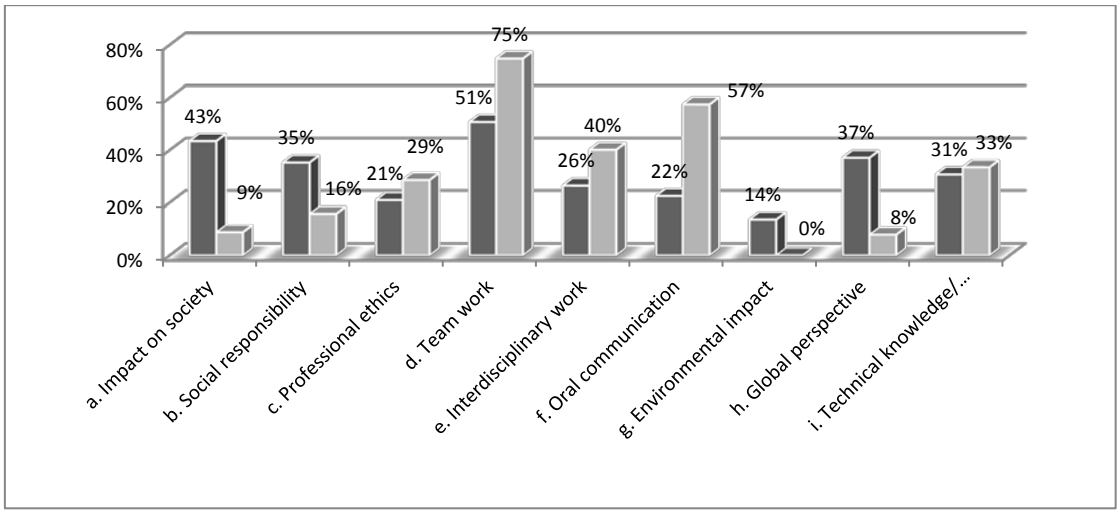

Figure 1: Fraction of students that selected each item. Light bars indicate percentage of respondents that selected item as a consequence of the COMFIE program. Dark bars show the students that attribute the item to be a consequence of the project work. Team work (D) and Oral and Written communication are clearly perceived to be strengthened. And the environmental aspects were almost completely ignored; item i on that graph should be interpreted as Engineering Technical Knowledge in their project work while for the COMFIE program it means Adaptation to College Life.

Another skill that was developed through the projects was oral expression. Students refer to this ability in the following terms: they feel more confident in public speaking, show a better anxiety control, and have improved in the use of technical vocabulary. In addition, they feel more connected to the public, prepare a much better visual material (slides and posters) than that at the beginning of the term and are able to organize information despite of complexity of the concepts involved.

At the same time the different nature of the projects per career generate enthusiasm with proposals questions, the skills developed with the project and the final presentation have contributed that participants feel more confident and aware of the role of the engineering in the society.

5 Conclusions

A survey was designed to assess the impact of the program as implemented. From the students' responses to the survey, it can be ascertained that the COMFIE program responds to some basic concerns in the education of future engineers from the very beginning of their studies. Progress in these aspects is evident from the results of a Project Day event. This progress has been recognized by academic peers as well as the general public attending the event.

The incorporation of the methodology into the Introduction to Engineering course work has contributed to strengthening the competences to be developed during the course. And most of the development has been influenced by the classroom activities. Motivation has been a pivotal point for the success of project work in our courses.

Public oral presentation of the project results has conducted students to use a more technical and formal language. The quality of the oral presentations has also improved. A notable improvement in the quality of oral communication, in general, has been observed.

Students have described the experience of working as a team as one that has led to the improvement of social skills. They have also characterized its results as an opportunity to grow and evolve. They recognize the reinforcement of critical thinking skills as a product of their team work. On the other

hand, they mention the attitude and availability of the instructor as a major factor contributing to strengthening the teacher-student relationship.

The classroom activities have been mentioned by students as very significant in deciding to continue with their studies in the selected major. They also highlight the feedback activities, and the opportunity they provide to relate more directly to their respective field, as important in that choice.

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