

# Teamwork and innovation competencies: A first semester engineering students hands-on course

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**Abstract** - This article presents a set of oriented actions to reinforce the engineering students' competences in teamwork, innovation and entrepreneurship. This aspect is specially considered in three stages of the engineering studies: in first semester (focus of this article), during two semesters in the middle of the engineering studies, and in the last semester. The actions presented are in the context of a global curricular reform of our undergraduates engineering programs in the University of los Andes. This article presents an analysis of *ExpoAndes*, an activity with the students of first semester of engineering. These students face the challenge of building a team to make an innovating proposal from different engineering disciplines perspectives. This activity is supported by professors, managers and engineers. Every semester approximately 600 students have participated in *ExpoAndes*. It also develops three competences and skills: Team work, Observation of problematic, Exploration of a solution. This article intends to analyze how first semester engineering students are being motivated to develop the forgoing competences and to analyze the strengths and weaknesses of the process. Based on this analysis we want to start to evidence a coherence with the proposed activities in the half and in the end of engineering undergraduate program.

*Index terms* – Hands-on engineering activities; Innovation first semester engineering ;Teamwork first semester engineering

## INTRODUCTION

In the traditional conception of education regarding engineering, the reinforcement of competences that allowed the professional future to face the complex problems in society in an innovative and flexible way, was not explicitly necessary. The challenges that an engineer faces now a days, should allow he or she to develop observation skills and, therefore, to identify and define real world problems creatively, to design processes and implement solutions to optimize and improve the product or the proposed process. These ideas are the result of an innovative education program designed, adopted and implemented by various institutions of engineering education [1]. In this program there are standards that allow guiding the performance in modern engineering education, on one hand; and on the other

hand the results of the learning process define what an engineering student should develop to face the new challenges that society presents. These results are classified in categories: personal (student's performance in solving problems, to live and experience situations, to have creative and critic thinking, and to develop professional ethic concepts), interpersonal (to develop team work, leadership and communication skills) and the ability to develop products and systems (conception, design, implementation and system operation in social contexts).

In the same line of action the ABET[2] has incorporated similar characteristics in their recommendations, in order to guarantee the quality of engineering education. Universities have also made contributions associated to innovation in engineering education. These universities develop projects during the first academic period; some of them are: University of Colorado at Boulder [3] , MIT [4], Chalmers, Caltech, Universidad de Maryland en Collage Park [5], Universidad de Massachusetts en Amherst [6] Universidad de Pittsburgh [7].

The Faculty of Engineering of University of Los Andes in Bogotá, has been analyzing and reformulating its program of study in altars to lead innovation, they have strengthen and incorporated several characteristics that have been mentioned before. The Engineering School Renovation Project has concentrated efforts into four areas, one that emphasizes "A reflection on both undergraduate and graduate education, which resides dealing with content, incorporates a search for new competences in an international context (demanding international competences). Innovative curricular and methodological proposal are essential in this reflection." [8]

It is within this context, where the project *ExpoAndes* has taken place with first semester engineering students. *ExpoAndes* is how the engineering students projects show is known, for this matter collaborative work teams are created to begin a investigation task to identify a particular problematic and its possible engineering solutions [9]. *ExpoAndes* has become in the first opportunity students have to develop in teams projects that would presented at the end of the period to family, other engineers, businessmen,

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teachers and people on the public sector of the country. During a whole day about 120 projects are presented to around 2000 people, who have the opportunity to interact with students from different areas of the engineering faculty (general, industrial, systems and computers, electrical and electronic, civil and environmental, chemical).

### **EXPOANDES: TEAMWORK AND DEVELOPMENT OF COMPETENCES OF ENGINEERING FIRST SEMESTER**

During the last ten years ExpoAndes has had a few changes. Before 2002 only Industrial Engineering students participated in this activity, in 2002 interdisciplinary groups with general, industrial, systems and computers, electrical and chemical engineering students were conformed ; since 2004 first semester students from all areas of engineering participate conforming non- interdisciplinary groups.

The interest with ExpoAndes is to develop initial competences according to the type of engineer that faculty wants to form, which means: "Engineers who are capable of identifying and analysing the problems of their times, of interpreting social needs, and responding to them with solutions based on an understanding and mastery of science, mathematics, technology, and engineering methods. Engineers who become leaders and guides of their own societies in what concern to the identification, appropriation, usage, and generation of those technologies that can best contribute to their sustainable development. Engineers who can assume a leading role in the creation and triggering of technologically-based enterprises whose leadership contributes to the country's business development" [8].

Based on that, six categories were defined for students to work on while making their first semester project: Learning Process, Teamwork, Innovation, Engineering approach, Entrepreneurship and Motivation. Find description of categories below.

- Learning Process: In this category variables that affect the appropriation of the project during the semester are taken into account. For this matter the impact on the learning process, related to the resources that students have to develop the project, is considered (bibliography, class sessions, teachers' preparation, technologic resources, etc.). What is meant with this category, is the observance of how two important topics affect the learning process: The way in which the student faces the identification of the idea for project he or she wants to develop, and also the meaning of having to present their idea in an open event to other students, engineers, businessmen, teachers and general public.
- Teamwork: What is intended with this category is to analyze the extra value of making in group an

engineering project. Aspects related to personal evaluation amongst a team, and the impact of developing a project along with other engineering students, are taken into account. In addition, the contribution of ExpoAndes in the development of oral, written, and communicative skills, as well as the use and application of theoretical concepts studied during the semester are regarded.

- Innovation: In this category aspects related to the student's innovative approach to the whole elaboration process of their engineering project are analyzed. Other perception variables associated to innovation in the solution offered by the project, and to how innovative is the learning process itself during ExpoAndes are also observed.
- Engineering approach: This category seeks to identify the theoretic contribution associated to the engineering tools that a student of first semester is confronted. This is a form to observe the contribution of the engineering professor, the perception regarding the use of the tools of each discipline to develop the project, to express themselves, to communicate an idea, to write a technical report, to work together with other engineering students, to design and engineering solutions, to identify problems and its solution design.
- Entrepreneurship: This category seeks to observe how an activity such as ExpoAndes that includes engineering aspects, teamwork and innovation, contributes to a first approach to a proactive attitude of a student that is beginning its learning process in the faculty.
- Motivation: In this category aspects related to the student's disposition towards a project of this level in the first semester is evaluated. Additionally, it is intended to determine the level of satisfaction that this type of projects generates, related to the fact of studying engineering. This is made to determine the importance that students give to the development of the projects, and the need to make a similar project in their education near future.

### **HANDS-ON ACTIVITY: A STUDY OF STUDENTS' PERCEPTION**

#### **The Research**

The main objective of the analysis that is to be presented is to make evident the perception that students have regarding the project that they develop in ExpoAndes, based on the six categories mentioned above. For that matter, a sample taken made possible to identify three different groups of students that have participated in ExpoAndes; the ones that are finishing their career, it means the ones that participated on ExpoAndes 2002; the ones that are in the middle of their studies, they participated on ExpoAndes 2004; and those that are at the first phase of the career, the participants on ExpoAndes 2006.

## Students Profile

To determine it, a survey was made to 316 students, which represents approximately 10% of the students that have participated in ExpoAndes during the last five years. The 41% (*senior students*) of the students are assisting their last semesters and 59% (*recent population*) are in the first years<sup>4</sup> of their engineering formation. The 70% of the interviewed belong to industrial engineering, 14% to chemical engineering, 8% to systems and computers and the rest are distributed in mechanical, electric and electronics, and civil and environmental engineering.

The survey makes evident dummy variables (yes/no) and variables to be evaluated with values from 1 to 5 (where 1 is a bad score, and 5 is an excellent score). The results of the study, to be presented, allow having an approximation to the perception that both samples of population have (senior and recent) regarding the categories explained before. Afterwards the results of perception from senior and recent population from industrial and chemical engineering are presented (samples' most representative).

## Results per Category

### Process

For senior students, as well as for recent students, 70% of the variables related to this category were scored with values between 3 and 4. For the senior population, class sessions are the ones that generate the highest level of dissatisfaction (mean= 2,42; std dev = 1,11), while for the recent population, the weakest part of the process is in the technologic information resources (mean= 2,29; std dev= 1,27). For both populations the better perception is related to the learning process of ExpoAndes is associated with personal performance results (mean= 3,89; std dev= between

0,75 y 0,82). The perception of the students is similar, when a discriminated analysis by department is made<sup>5</sup>.

### Teamwork

100% of the variables in this category were evaluated by senior and recent students, with values between 3 and 4. For senior students the perception of teamwork is more positive, that for recent students (senior: mean=3,84, std dev=0,88; recent: mean=3,70, std dev =1,12). For senior students the lower perception regarding teamwork is associated with the development of oral expression skills (mean=3,26; std dev =1,168); for recent students the major weakness is also associated with the development of oral expression skills (mean=3,26; std dev=1,168). Those who perceive the higher weakness regarding oral expression skills are industrial engineering students (mean=2,99; std dev=1,17); chemical engineering students think that the weak spot is in the development of effective communicative skills (mean=3,33; std dev =1,09) and that the strongest aspect is related to writing skills development (mean=3,85; std dev=1,001).

### Innovation

Senior students consider that 70% of the variables associated to the category are in scores between 3 and 4 (the remaining 30% are perceived with scores between 2 and 3). For these students the innovative strength that they develop the most is the design of solutions for a problem (mean=3,61; std dev=1,01) and the foremost weakness is the process design (mean=2,79; std dev=1,23). For recent students the perception is the complete opposite: the main strength is related to process design (mean=3,04; std dev =1,164) and the weaker aspect is related to innovative engineering solutions design (mean=3,53; std dev=0,98). The results by department highlight similar behaviors amongst those of industrial and chemical engineering.

### Engineering approach

For 80% of senior students the variables concerning this category are evaluated with values between 3 and 4; for recent students all variables were rated between 3 and 4. For former students the weakest point of the category is the application of theoretical concepts to the project (mean=2,71; std dev= 1,200); for new students the biggest concern is related to ExpoAndes' contribution to the development of the project (mean=3,04; std dev=1,16). For all students the most favorable perception is associated to teamwork (mean=3,84; 3,70; std dev=0,88; 1,12). Separating the results per department, industrial engineering students

<sup>4</sup> For survey engineering students that are developing their projects at the present time (2007-1) were not taken into consideration.

<sup>5</sup> Bear in mind that the departments taken into account are industrial and chemical engineering.

consider that the weaker point related to the engineering approach is process design (mean=2,82;std dev=1,11) and for chemical engineering students is the lack of application of theoretical concepts to the project (mean=3,14;std dev=1,025). The best perception for industrial engineering students concerns teamwork (mean=3,72; std dev=1,022), although for chemical engineering students are writing skills development (mean= 3,85; std dev=1,001).

### Entrepreneurship

In this category, the evaluation of ExpoAndes' importance when it comes to promote entrepreneurial attitude within students, was the main variable taken into account: Former students (mean 3,51; std dev=1,29) and recent students (mean=3,53; std dev =0,98). An interesting difference is perceived when comparing the departments' results. For chemical engineering students (mean= 3,76; std dev =1,22) there is a better perception concerning the development of entrepreneurial skills, than for industrial engineers (mean =3,17; std dev =1,46).

### Motivation

The variables associated in this category are evaluated by all students (senior and recent) with rates between 3 and 4. 67% of senior students consider very helpful to make processes like ExpoAndes during their career. The higher interest for senior students, 74% considers important to develop a similar process while their undergraduate studies. The interest is a higher in chemical engineering students (68% of industrial engineering students consider necessary to make this process later in their undergraduate studies; 71% of chemical engineering students think that is necessary to reinforce this process in a near future while studying).

## DISCUSSION

The aim of the research was to identify the strengths and weaknesses that engineering students identify when they face a non traditional learning space such as ExpoAndes. The perception of the students that have had the experience of participating in ExpoAndes is moderately good in aspects like learning process, development of teamwork and engineering innovation skills, and also to use the engineering approach to solve problems and to undertake new projects.

Without a doubt, the major strength that has been developed in ExpoAndes, is the ability to generate solutions by *working together*. Very interesting aspects are observed in this category. The best results of ExpoAndes' evaluation about teamwork were given by senior students, those who are in

engineering's last semesters. The a priori hypothesis that the research group makes about this matter, is related to the fact that these students had the first opportunity to work within interdisciplinary groups. This was the first stage of change for ExpoAndes, where engineering projects were made by students from industrial, chemical, systems and computers, and general engineering. This project required a complete involvement of the students, as well as of the commissioned teacher. The identification and solution of the treated problems indicated, that the knowledge regarding each discipline was needed. Another interesting outcome is the necessity to develop, in the students communicative and oral skills. It is worth saying that both types of students, the ones that participated in interdisciplinary groups and those who did not, thought that they have not developed oral expression skills. Part of the assumption that the research group propose about it, is related to the high exigency demanded from students when is asked that they present the project during a whole day, in an open show with over 2000 guests including family, businessmen, engineers and teachers. Although they have to be proficient explaining their project, it would be helpful if they had to face oral presentations for partial exams. This way a permanent systemic training would be guaranteed.

ExpoAndes becomes an opportunity for teachers to guide students in observation, identification and design with an engineering approach. Even though it is clear that it is not expected that students in their first semester find a solutions as engineers to a given problem, it is intended that they experience a situation similar to what they are going to face when they become professionals. The perception of ExpoAndes' engineering approach is better for recent students than for former students. The main weakness for senior students is the difficulty they had to use theoretical concepts while developing the project. The supposition presented after having this result is that once ExpoAndes got through the interdisciplinary conformation phase, a considerable effort was made to make possible effective teamwork, therefore the development of specific engineering tools was left aside. Another theory with the last result could be connected to the fact that when interdisciplinary groups were formed, the emphasis was made in engineering themes associated to disciplines that were more relevant in order to resolve the specific problem; if this assumption is valid, a group of students that participated in the interdisciplinary scheme had more grounding than the other.

A learning process like ExpoAndes seeks the development of an entrepreneurial attitude by which the engineering student, from first semester, is able to identify the opportunities that generate a real value. About this, former students perceive that the major strength is the innovation in the process of designing a solution for a problem. However the perception is the contrary amongst recent students. An assumption related to the opposite results, even though it is very strong, could have a relation with the two approaches ExpoAndes had in the last years. New students had to develop the design

of the solution taking only into account their own discipline. The question worth asking is, its interdisciplinary teamwork a factor that foments the innovation ability of designing an engineering solution?. These first results make it think that it could. However it is important to explore in a deeper way such a strong affirmation in the middle of a learning process.

ExpoAndes presents itself as a possibility to stimulate the student to develop abilities as an entrepreneur. The most important opportunity presented in this field consists in exploring if each one of the departments has been able to develop that competence. The investigation made so far allows only preliminary results. Because of this the challenge presented to the researchers, consists to promote investigation in order to deepen into this particular subject.

## CONCLUSIONS

The study presented intents to show from the students' perspective ExpoAndes' strengths and weaknesses as a "hands-on" intervention in engineer's education, during their first semester. The different aspects: teamwork, innovation in engineering, use of engineering standpoint to solve a problem, and embark on projects that were approached in the study.

The research will continue, to deepen into each one of the categories presented (with first semester students) by one side, and with the perception of the teachers, businessmen, and engineers who participate in ExpoAndes, by the other.

It is observed in this initial approach, that students' motivation to this kind of projects compels them to develop fundamental abilities and competences for an engineering student that the University is forming. In this first exercise with teamwork projects that search for innovation using an engineering process, it possible to determine student's perception concerning teamwork impact, the need of a method, and general characteristics of innovation based on technology. Because of eventual inconsistencies in our instrument, the conclusion about the impact on entrepreneurial competences is not as clear.

ExpoAndes is an approach to non traditional educational schemes for engineering students at the University of Los Andes. With this method the teaching has tried to integrate not only all disciplines, but students, teachers, engineers and businessmen. This study made evident the strengths and weaknesses of the process from the students' perspective. The investigation will continue to deepen in each one of the categories presented (with first semester students), as well as with the analysis of the perception teachers, businessmen and engineers who participate in ExpoAndes have.

In this initial approach it is observed that students' motivation to this kind of projects compels them to develop fundamental abilities and competences for an engineering student that the University is forming. This is considered a significant step in the middle of the curricular reform general framework. Is the key to continue with the development of this abilities and competences throughout undergraduate studies. For that matter, there are similar schemes presented in the middle (at present time Systems and computers Department is developing the innovation and entrepreneurial process in the middle of the career.)and at the end of the career, within the reform context.

Identifying the strengths and weaknesses at the first phase that engineering students go through, is a valuable occasion to get deeper in the opportunities that these type of projects have for the engineer, in order to be prepared to build up competences in innovation, entrepreneurship y teamwork that present day society requires.

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