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Project-based learning and use of the CDIO Syllabus for geology course assessment

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ABSTRACT: This study provides an overview of the development of hard and soft skills from project-based curriculum planning, and suggests ways to evaluate them in the context of engineering education and their importance in the training of future engineers. The research described here is descriptive and analytical, involving a detailed study to determine the skills generated by the end of the semester. Data collection was performed by applying a questionnaire of closed assertions with five levels of response, consisting of 24 items based on the proficiencies established in the CDIO Syllabus to geology course students. From the results obtained, it seems that students have high expectations in relation to the competencies generated, and it became evident that students have a good level of intellectual capital, but they have poor non-technical skills. The main student perceptions regarding the impact of the course were associated with the ability to obtain a positive outcome the end of the course, and the need to gain the theoretical background knowledge of a basic science course as the common core in engineering.

Keywords: CDIO Syllabus, project-based learning, skills, engineering students

INTRODUCTION

The long-term vision that universities have must be related to at least the changing international environment, international treaties and the exchange of roles between university-industry-state. The new paradigms of the knowledge society in education require the development of strategic and creative thinking to solve complex problems and generate real innovation, based on the need to understand how educational processes occur and are verified to meet the goals of transforming society. That is why the current understanding of how knowledge is acquired and the learning processes that develop indicate that engineering education must include a set of learning experiences that enable students to build a deep range of knowledge, develop their skills, and technical and professional skills and to apply them to a large number of educational projects in engineering [1].

Within the engineering pedagogy, it must be remembered that students learn in many different ways, such as by seeing, hearing, thinking, acting, drawing analogies and building mathematical models in the area of science and technology [2]. In this vein, university engineering programmes should educate students not only in the technical disciplines, but also in a wide range of personal, interpersonal and systematic skills [3].

Current engineering education can be seen as mismatched with the current demand for engineers in *the real world*. On one hand, there is the need for engineering graduate students with a broad technical knowledge and, on the other hand, there is a growing need for engineering graduates to possess attitudes, attributes and personal and interpersonal skills that enable them to develop successfully in the professional world and be able to design, produce and manage new products and/or systems [4].

Therefore, there must be a rational, comprehensive, consistent and generalisable engineering education system for meeting the learning objectives of engineering at the undergraduate level. Therefore, engineering education programmes taught to university students should cover the wide array of knowledge, skills, attitudes, and skills necessary to convert them into successful engineering professionals.

Several studies and initiatives have been developed to recognise, identify and recommend which criteria and practices are more suitable for curricular changes in engineering education worldwide. Currently, the global trend in university training is to foster more student-centred learning, to create a more interactive and motivating learning environment for both students and teachers [5].

Within the context of the transformations and implementations, the engineering curriculum must be designed according to, at least, three key recommendations [6]: a) engineering schools must develop the best educational practices based on pedagogy, in new technologies and interdisciplinary areas, to promote learning by students and ensure retention; b) there should be teaching strategies to improve engineering education, with teachers having sufficient resources and materials to enable them to deliver a demonstrable engineering education, address and support global needs and global standards within [7]; and c) develop an engineering pedagogy in close correlation with the needs of society and industry to strengthen genuine education and training of engineering students. In this vein, a mapping of expected competencies is required, in order to assess the current status of curriculum planning in geology courses according to the perceptions of third year civil engineering students.

Curriculum planning was based on project based learning (PBL) as the pedagogical basis for creating, training and promotion of generation *soft and hard skills* and a future contrasts with other instructional practices for teaching engineering.

The CDIO Syllabus (Conceive - Design - Implement - Operate process) based on the common denominator of engineering students in their academic and professional training was taken for skills assessment criteria. Students should be able to: Conceive - Design - Implement - Operate real systems engineering projects [8-9].

MATERIALS AND METHODS

The research undertaken was descriptive, analytical and field type. A detailed study was conducted to determine whether there were any soft and hard skills generated in students after completion of the semester. The presented research was conducted within the scope of the geology course, for the second semester of the third year of the civil engineering programme. The overall objective of the course is to train civil engineers, so they are capable of understanding the importance of solving geological problems in a civil engineering context.

The planning of the course was based on the PBL principles and a series of scheduled activities was developed and conducted through the semester: academic activities within and outside the classroom, master classes, days out; demonstration laboratories, field trips and visits, documentary analysis and reading technical reports, supported by the use of *open educational resources* [10] and a project by the time the course was completed. Additionally, mobile technology tools, type smartphones (with their free apps) and software were used for the purpose of developing the engineering student.

The second phase of planning the course involved the conduct of fieldwork for three consecutive days (named Expogeologira 2013 - geology exhibition tour). In this, students were grouped into five teams, to carry out various course-related activities. Skills acquired or developed throughout the course were assessed, mapping both perceptions and the degree of learner importance, specifically, there were soft skills expected to be developed and demonstrated in the course. Furthermore, teacher assessments of student skills were communicated to the students on completing the First Student Survival Contest of Engineering - SCSE-2013 - during the Expogeologira. In this activity, the various teams were required to design and conduct field-engineering operational functions/operations, based on knowledge acquired throughout the academic semester, which was accompanied by the observation their generic skills. In the second semester of 2013, 39 students were enrolled in the course.

Data collection was performed by using a questionnaire consisting of 24 items with multiple choice closed assertions with a five-point Likert-type scale. The evaluation of students' proven competencies was made by teachers in the field, during SCSE-2013 and these were divided into two groups: soft and hard skills as shown in Table 1:

Table 1. Classification of skills assessed in the field by the teacher.

Type	Skills assessed
Soft skills	• Confidence • Ability to take decisions • Voluntary readiness to help • Artistic and creative skills • Ability to interact with others • Punctuality
Hard skills	• Cognitive engineering skills • Results practical engineering expected • Ability to implement theoretical knowledge acquired • Ability to use technology • Technical written and oral communication skills

In assessing student competencies via the implementation of an *ad hoc* questionnaire, soft skills were divided into two clusters as a presented in Table 2.

Table 2. Clusters and distribution criteria of skills valued by students on their perception and importance.

Clusters	Skills
Interaction	• Ability to recognise personal tastes and preferences • Ability to interact with others and be friendly • Ability to work in teams • Ability to adapt to different situations • To feel affection and empathy • Be neat and tidy • Be sociable • Be punctual • Be aware: be organised, responsible and able to work hard • Be able to work alone • Be nice
Motivation	• Having enthusiasm • Have a positive attitude towards work • Be committed • Be confident with yourself • Be willing to learn • Be curious • Willingness to participate in extracurricular activities • Having defined objectives

A Likert-type scale was used for the learners' perceptions questionnaire and the proficiencies referred to in the CDIO Syllabus were addressed in the instrument. These are listed in the table below.

Table 3. Proficiencies addressed in the assessment tool of the course.

Symbol	Proficiencies
P_1	Implement prior knowledge in basic engineering sciences
P_2	Implement knowledge of at least one course of common core
P_3	Implement knowledge of at least one course specialty
P_4	Development of engineering reasoning
P_5	Implement engineering experimentation and expertise.
P_6	Implement holistic development of critical thinking and knowledge
P_7	Development of responsibility, tolerance, ethics, friendship, time control, enthusiasm, punctuality and personal goals defined
P_8	Development of engineering thinking, responsibility, organisation and hard work
P_9	Ease of teamwork
P_{10}	Ease of writing and fluency in oral defences
P_{11}	Ease of reading technical language (English)
P_{12}	Ability to search for information; contact with professionals; social and environmental responsibility
P_{13}	Present views and development of extracurricular activities
P_{14}	Ability to design, implement, innovate and invent
P_{15}	Ability to obtain a final product or system

RESULTS AND DISCUSSION

Once the instrument had been developed, including the views of students on the planning and development of the course, the associated items were randomised to each of the four skill areas of the CDIO Syllabus, as presented in Table 4. In the validation of the *understandability* of the instrument, it was possible to determine the overall internal consistency resulting in a Cronbach alpha coefficient value of 0.90.

Cronbach's alpha test indicates that if the coefficient is greater than 0.9 the fit is excellent; in the range of 0.9 to 0.8 the instrument is good; between 0.8-0.7 the instrument is acceptable; in the range 0.7 to 0.6 the instrument is weak; between 0.6 to 0.5 the instrument is poor; and if it is less than 0.5, it is not acceptable [11]. It can, therefore, be concluded that the questionnaire was appropriate for the purpose for which it was designed.

Table 4. Items' distribution by proficiency according to the CDIO Syllabus.

Proficiency	Item number	%
C - Conceive	1, 2 and 3	12
D - Design	4, 5, 6, 7, 8, 9 and 25	28
I - Implement	10, 11, 12, 13, 14 and 15	24
O - Operate	16, 17, 18, 19, 20, 21, 22, 23 and 24	36
TOTAL		100

DEVELOPMENT OF SCSE-2013

The students participating in SCSE-2013 had to select various working committees, i.e. logistics, catering and transportation, within which to perform all activities designated for each committee.

Parallel to this, teachers evaluated students during SCSE-2013, in terms of their soft and hard skills in the following: hiking, recreation and sports, voluntary cooperation and support, academic poster and paper presentation, and an oral sustaining project. The results were weighted for each of the five teams and are presented in Figure 1.

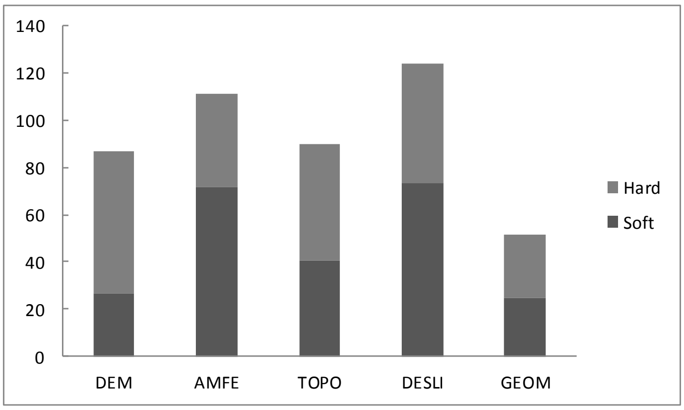

Figure 1: Students' soft and hard skills in the SCSE-2013.

From the group participants in SCSE-2013, it can be observed that the DEM group was the one with more hard skills, while the AMFE group had higher levels of soft skills; however, the DESLI group, was weighted with higher levels of technical and non-technical skills both in-class and out-of-class.

This shows that some students have intellectual capital that is cognitively good with excellent technical skills, but have non-technical skills weak [12]. This goes against the literature in which soft skills along with technical skills are valued, due to the competitive and global marketplace [13].

Future engineers should be able to undertake projects with human, material and financial resources. That is, there must be a *balance* between technical and non-technical competencies [14], as evidenced by the TOPO group, which are necessary to successfully enter and have professional sustainability in the labour market. This is why all skills should be encouraged and worked in engineering education classroom [15].

DATA ANALYSIS

The questionnaire allowed for the determination of the relationships of student responses through the analysis of perceptions of what has been achieved in the course in view of expectations. For the analysis and interpretation of the results, the following classification ranges were established according to the scales used in data collection:

Range 1: perceived expectancy ≥ 1.5 = *Very Good* rating scale.
Range 2: perceived expectancy ≥ 0.5 and <1.5 = *Good* rating scale.
Range 3: perceived expectancy ≥ - 0.5 and <0.5 = *Regular (Average)* rating scale.
Range 4: perceived expectancy ≥ - 1.5 and <- 0.5 = *Poor* rating scale.
Range 5: perceived expectancy ≥ - 2.0 and <- 1.5 = *Very Poor* rating scale.

ANALYSIS OF ACHIEVED EXPECTATIONS

The planning and execution of the course took into consideration the proficiencies established on the CDIO Syllabus. The students in the course consisted of 51% of male students and 49% of female students. Overall, it was observed that

13.4% of students expressed their dissatisfaction and/or expectations regularly achieved after the course, with dissatisfaction levels being a little more evident in male students.

To find the weaknesses in the planning and development of the course in question, cluster analysis was performed in regard to soft skills and other analysis was performed based on encodings. In this regard, it must be described in terms of the levels achieved relative to expectations, specifically, non-technical skills - soft skills of the clusters presented in Table 2; 24.6% of students reported being regular (average) or completely dissatisfied with unfulfilled expectations achieved in this type of competition at the end of the course. Of the two clusters presented, Inspiration was the highest degree of regularity, dissatisfaction and/or completely dissatisfied (71%).

It is worth remembering that this cluster encompasses soft skills ranging from the recognition of personal preferences, work in teams, empathy, sociability, punctuality and being pleasant. In this regard, the American Society for Engineering Education (ASEE) emphasises this need [16] and the literature consulted states that engineering students must have skills for teamwork among their soft skills [17]. The results are presented in Figure 2.

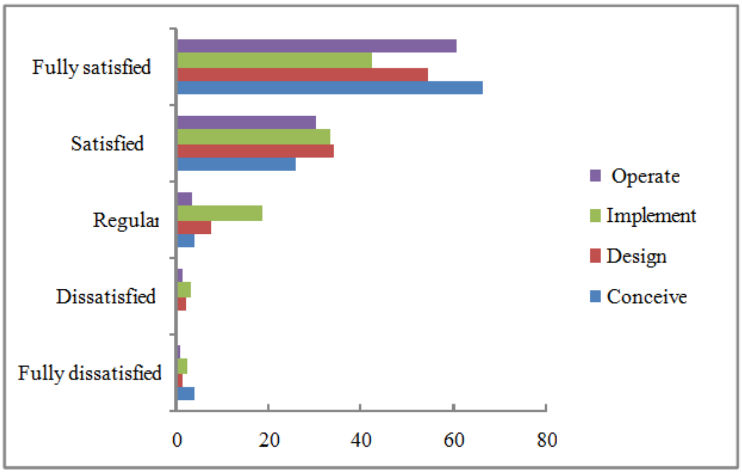

Figure 2: Perceptions expectations achieved in the CDIO Syllabus encodings.

It can be observed that the students reported higher levels of satisfaction than dissatisfaction and that of the first, the Design syllabus, followed by the expected Operate met students' expectations after completion of the academic semester.

These results provide a framework for students, in which the curriculum emphasises programming implemented in the fundamentals of engineering within the context of the Conception - Design - Implementation - Operation; systems and real-world products should be adopted as a framework for planning, processing and engineering curriculum based assessment results [18].

PROFICIENCY ANALYSIS

A graph on expectations achieved for each of the 15 proficiencies presented in Table 4 is shown in Figure 3.

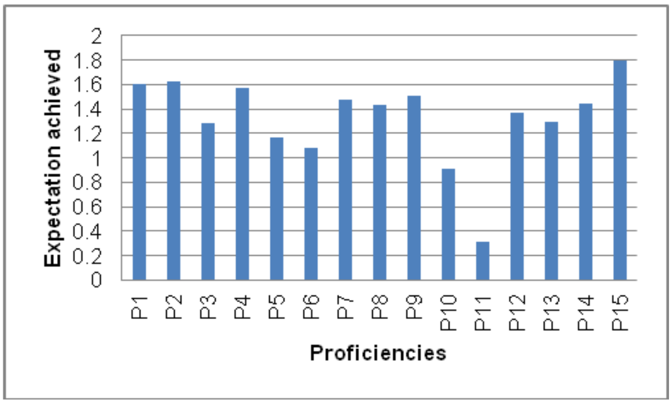

Figure 3: Expectations for the studied proficiencies achieved in relation to the impact of the course.

Analysing the above figure, it is observed that proficiency P15 (ability to obtain a product or end system) has the highest expected impact, according to the perception of students; followed by proficiency P1 (ability to implement previous knowledge in basic science of engineering) and proficiency P2 (implement knowledge of at least one course of the common core of the academic studies).

Similarly, students expressed lower expectations regarding proficiency P11 (ease of reading technical language - English), followed by proficiencies P10 (ease of writing and oral fluency underpinnings) and P6 (implement knowledge holistic development of critical thinking).

Finally, the overall evaluation of the geology course based on the achieved expectations, as perceived by students was 1.35, which according to the range's classification established, is considered good.

CONCLUSIONS

Upon completion of the investigation, it can be concluded that:

- It is necessary for there to be a level of engineering education curriculum planning so that students have an active role in their learning.
- It was evident that some students have good intellectual capital and have excellent technical skills. This partly goes against what is currently desired in engineering students; therefore, it is necessary to work on teaching programmes in this regard.
- The main student perceptions regarding the impact of the course evaluated are associated with the ability to get a positive outcome at the end of the course and the need to implement knowledge of basic science as the common core of engineering.
- From the results obtained, it is interpreted that students have good expectations in relation to the geology course and their performance in future as professional engineers.

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BIOGRAPHY

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