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Preparing Students for Success in Engineering Degrees: A Combined Strategy Between High School and University*

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A combined strategy for improving students' recruitment, academic performance and retention rate during the last year of high school and the first year of engineering programs, including Mechanical Engineering, Electrical Engineering, Industrial Electronics Engineering and Software Engineering, was conducted in collaboration with high-school teachers, university teachers, and peer-mentors. The entire working group included four high-school teachers, eight university teachers, four third-year university students, and sixty six last-year high-school students. During the first year of the experience, the working group analyzed the main weaknesses of the students in terms of knowledge and skills needed for their entrance to engineering degrees. Specific activities were designed and put into practice. During the second year, a mentoring and peer-mentoring strategy was established with the goal of giving students better information and advising about university services and resources as well as about the subjects of and strategies for studying. With this two-year combined strategy, the academic performance of freshmen was substantially improved, with significant differences in comparison with the students who did not participate in the project.

Keywords: outreach activities; peer-mentoring; tutoring; students retention; academic performance

1. Introduction

The time needed by graduates to find their first employment in the field of engineering is very low in comparison with other fields in Spain (from 2.6 to 4.7 months depending on the engineering degree; 8.8 months in education; 8.4 months in law; 7.5 months in the sciences; 7.4 months in the social sciences; 6.1 months in the humanities; and 3.9 months in health sciences) [1]. Similarly, in the UK, there is evidence that the demand for graduate engineers exceeds the supply. This phenomenon can be observed in the persistent wage premium for people with engineering degrees [2]. In the US, professional and technical services accounted for the majority of growth in January 2015, adding 33000 jobs [3]. Nevertheless, the rate at which Spanish students choose to study in the sciences, mathematics and computing; engineering, manufacturing and construction; and engineering trades is decreasing or stagnant [4]. Likewise, the number of engineering enrollments decreased from 6.3% to 5.4% in the last decade in the US [5]. This decline may be due to the lack of engineering and math in school curricula, which makes students tend to overlook engineering as a career selection [6, 7]. To increase the number of students entering engineering degrees, it is necessary to increase students' interest in science, technology, engineering and mathematics (STEM) [8, 9].

According to the PISA report [10], fifteen-years-old Spanish students have mathematics, sciences and reading levels that are significantly below the average of the Organization for the Economic Co-operation and Development (OECD). The top country on this scale is China, whereas the average level corresponds to the Czech Republic, France, the United Kingdom, Iceland, Latvia, Luxembourg, Norway and Portugal. The two top countries below the average are Italy and Spain. These data are particularly striking because most of Spain's neighboring countries are average or above average. The report emphasizes that proficiency in mathematics is a strong predictor of positive outcomes for young adults and influences their ability to participate in post-secondary education and their expected future earnings. The actual level of Spanish students is even more concerning because the assessment is not intended to measure what students know but what they are able to do with their knowledge in terms of practical skills, which is the most interesting issue for engineering degrees. Therefore, both lecturers and university authorities should be concerned about students' entrance level into engineering.

In this sense, programs oriented not only toward the recruitment and retention of new students in engineering degrees but also to introducing engineering skills into high schools' curricula are highly needed [11–13] and much more when students don't have a clear idea about engineering [14]. A variety of

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experiences related to these issues have been conducted in recent years. A number of works reported that first-year courses in engineering have been highly criticized for offering little connection to engineering as a career [15, 16]. These authors proposed introducing first-year project courses with the goal of making connections between the theoretical and academic aspects of engineering and the professional practice of engineering in an attempt to help freshmen understand that engineering is a people-oriented profession that underpins both the economy and quality of life. They had good results for student retention.

Richerson, Furse, and Bergerson [17] attempted to introduce engineering-based curriculum modules and demonstrations in high schools for collaboration between high-school teachers, faculty members and undergraduate engineering students. The modules and demonstrations were revised and accepted, but the initial assessment showed that the project was not as effective as expected. Therefore, the strategy was changed in the following years with the collaboration of high-school teachers in a day-long workshop where they identified the way that these modules could fit their own curriculum. This improved version of the idea was much more efficient and gave high-school students the opportunity to become more familiar with the engineering fields and more interested in pursuing engineering careers.

DiDonato et al. [18] recognized the low interest in engineering degrees among young students in the US, particularly among girls. In their study, these authors developed a low-cost, short-term intervention consisting of two brochures designed specifically for boys and girls with the same basic information but with different nuances directed to each gender. They had good results with regard to engineering stereotypes and significantly increased engineering-related self-efficacy, utility and interest. MacBride et al. [19] identified common misconceptions among young people about the nature of engineering and the predicted shortfall between the numbers of students entering university engineering courses and the growing demand for high-quality graduate engineers. They went a step further by introducing engineering content into high-school curricula through collaboration between two university engineering departments and pilot high schools with the aim of facilitating students' entrance into engineering courses and easing the transition from high school to higher education. They concluded that the project demonstrated that involving researchers, policy-makers and practitioners of the school and university sectors to work together to address the problems mentioned provides real advantages for everyone concerned.

Sabo et al. [20], in accordance with the concepts mentioned above, introduced a lesson about STEM in one high school with the aim of involving students in the study and helping them understand engineering concepts in an attractive and innovative way. This type of lesson should be placed in relation with and introduced in the existing curricula, so the close participation of high-schools' teachers is needed. The students showed their satisfaction and interest in STEM activities that are related to the real world and that can have a societal impact. The authors remarked that the activity design must connect materials and concepts with the learning objectives in a way that engages the students in the learning process. Babb et al. [21] focused on the decreasing interest of students in STEM careers implemented a thermodynamics project which has the aim of designing rich learning environments that engage K-12 students in tasks that resemble the real work of engineering professionals. The main objective was to put the students in situations similar to those of the real engineering world, to promote their participation in research, design, tests, trouble-shooting and documentation and to give them the opportunity to obtain feedback from real-world, practicing engineers. The authors concluded that the project captured the interest of students in engineering and that these types of projects are a good way to outreach the work of engineers.

Although many of these outreach activities can be successful in recruiting students for engineering degrees and despite the growing demand for engineering professionals, the number of students who leave engineering studies remains high [22]. The reasons students leave engineering are complex and varied, but a loss of confidence due to poor academic results, a lack of motivation to withstand the rigor of an engineering degree, and a lack of belonging are identified as important factors [23, 24]. Palmer [25], proposed the use of students data stored in institutional systems to predict their academic performance and to obtain predictor variables to develop interventions to improve students success and retention. In this context, it is necessary not only that students have a good entrance into engineering degrees but also a program to ensures that students have enough information about university life, the resources at their disposal, and the tutorial programs to guarantee that they are able to pass the first years.

Mentoring has been widely described as an important strategy of human resources management in a variety of organizations, such as enterprises, schools, universities and government departments [26]. The functions of mentors fall into two realms: career functions, such as sponsorship, coaching, protection, exposure and visibility, and psychosocial benefits, such as encouragement, advice, feedback and clarity of identity. In this way, a number of experiences have been conducted to mentor freshmen during their first years at the university. Barrachina et al. [27] reported a mentoring program organized by the Polytechnic University of Valencia (Spain). Every freshman is assigned to a sophomore (their so-called "older brother") and to a mentor teacher with the aims of supporting and guiding students in their training process; identifying difficulties related to the content of the subjects; avoiding feelings of isolation and loneliness; encouraging the students to participate in the school; promoting the integration of new students in the school and the university; and developing the capacity for reflection, dialogue, autonomy, and criticism. These authors concluded that the participation of freshmen in the program reduced their likelihood of dropping out of their degrees during the first year and that participation helps students improve their academic records independently of their university admission grades. Similarly, Satyanarayana, Li, and Braneky [28] reported a successful mentoring program with a different hierarchical organization in which a faculty coordinator plans the work of mentors and tutors, and each freshman is assigned to a mentor. Furthermore, tutors are not assigned to specific mentees, but they hold office hours so that the students can ask them technical questions regarding their courses.

Akili [29, 30] reflected on the role of engineering teachers in a context in which students do not have all of the necessary skills for entrance into engineering careers, such as deep knowledge of math and science. In this context, teachers must accept that the students are not ready for the "ambient conditions" required upon entrance to the university, and they have to assume different roles in their relationship with the students. First, they are facilitators of learning; second, they must play the role of advisors, guiding students in their learning process; and third, in some cases, the relationships become mentoring. In such cases, the mentors must be accessible, share their experience openly, and have good communications skills. In this complex context, universities should have mentoring programs in which the role and the effort of mentors should be adequately defined and recognized.

The remainder of the paper presents an experience of recruitment and retention of students for the degrees of Mechanical Engineering, Electrical Engineering, Industrial Electronics Engineering and Software Engineering at the Polytechnic School of Córdoba University (Spain). The experience combines outreach activities in collaboration with high school teachers during the last year of high school studies with tutoring and peer mentoring during the first year of university with the same students.

2. Research design

The purpose of the study was to investigate the effect of a combined strategy using outreach activities during the last year of high school and tutoring and peer mentoring during the first year of university on the academic performance and retention rate of freshmen.

2.1 Participating staff

The project belongs to the general program aimed at improving teaching quality and promoting actions for educational innovation at Córdoba University (Spain). This program supports projects that reflect on and implement new teaching methods, including outreach activities in collaboration with K-12 institutions [31]. The current project received funds for two periods, 2012–2013 and 2013–2014. The participating staff of the project was divided into two groups: the university team and the high school team. The university team belonging to the Polytechnic School of Córdoba University included seven teachers from basic engineering subjects, such as Mathematics, Physics, Chemistry, Technical Drawing and Electrical Engineering, and coordinated by teachers of Project Management as well as four third-year students in each of the degrees of the school. The high school team included four teachers of four different high schools in Córdoba province, each with a group of students in the last year of secondary education who were interested in entering engineering degrees. Specifically, group 1 came from the city of Córdoba (Spain) and included 20 students, whereas the other three groups were from small agricultural and industrial villages within a radius of 80 km from Córdoba. Group 2 had 10 students, group 3 had 24, and group 4 had 12. Thus, the whole project team included seven university teachers, four high-school teachers, four university students and sixty six high-school students.

2.2 Procedure

The project's working procedure was organized during two years. During the first year, the entire project team worked with the students while they were still in high school. During the second year, the university team worked with the students, assisting and following them during their first year at the university.

The first year was organized as follows (Fig. 1):

1. Initial assessment of the students: during the first months of the course, an initial assessment of the students was conducted. The test contained 20 questions about basic concepts of General Physics, Mathematics, Technical

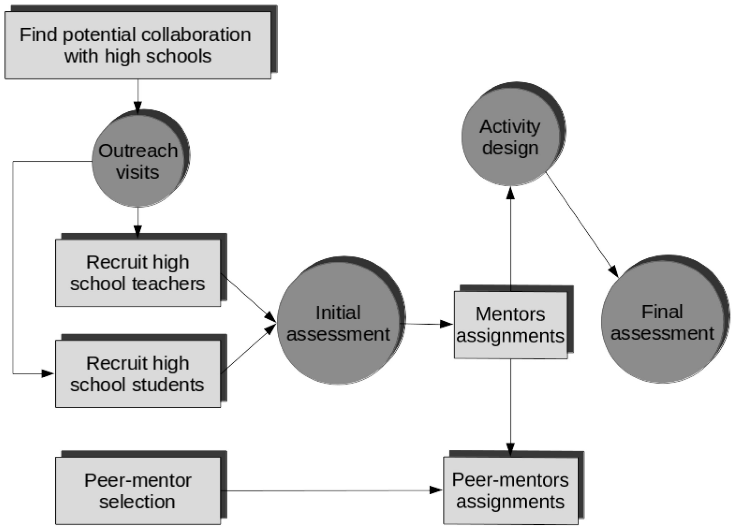


Fig. 1. First-year activities scheme.

Drawing, Electricity and Informatics. These questions were extracted from the Andalusian official curriculum of grades 11 and 12 [32, 33] and validated by 40 teachers of first year of the Polytechnic School of Córdoba University. Some examples of these questions are (multiple option): (1) If two bodies of different mass $m_1 > m_2$ fall freely from the same height and the friction force is null: (a) both reach the ground simultaneously, (b) the bigger one reaches the ground first, and (c) the minor one reaches the ground first; (2) The equation of a circle with center in C(4,–3) and with radius of 7 units is: (a) $(y + 3)^2 = 33 + 8x - x^2$, (b) $(x - 4)^2 + (y + 3)^2 = 49$, and (c) $y + 3 = 7*(x - 4)$; (3) About the scales of drawings: (a) scale 1:2 means that the size of the real object is half the drawing size, (b) scale 1:2 means that the size of the real object is twice the size of the drawing, and (c) scale 1:2 means that the drawing contains two objects and there is only one real object; (4) The ratio between voltage and current in an electrical circuit is: (a) capacity, (b) resistance, and (c) conductance; (5) Choose what of the following names is not a programming language: (a) Pascal, (b) Java, and (c) Windows.

2. Analysis of test results and assignment of mentors: after the analysis of the students' test results, each of the high school students was assigned to one university mentor depending on the weaknesses detected.
3. Nomination and assignment of peer-mentors: simultaneously with the process of phases 1 and 2, a call was launched in the Polytechnic School for volunteer students willing to participate in the project as peer-mentors or older brothers. The selection criteria of peer mentors among those who applied for the call were by number of passed credits and by average overall mark. Selected students were awarded two ECTS credits per year. The role of the peer-mentors was to be in contact with the high-school students and to guide them throughout the process of the project, connect them with the university mentors, and help them with the assigned activities.
4. Design and assignment of specific activities: teachers from the university and from high schools collaborated in the design of activities related to the weaknesses detected in the initial assessment in an attempt to improve the students' level of knowledge. These activities had to be related to the content of the high-school curricula, to avoid disturbing the normal work of the students, and to be easily assessed.

Once the initial assessment results were known, each student was assigned to a university mentor specialized in the subject in which the student had the poorest marks, and the mentors designed ad hoc activities to reinforce the weaknesses detected.

In particular, in the field of physics and mathematics, the students assigned to this activity visited the university installations and received a face-to-face session about general university services as well as a working session about the software Matlab. Afterwards, they were assigned an activity to be developed in the high school and with the help of their teacher and peer-mentors in which they had to search for concepts related to the general mathematical skills they were supposed to have at their university entrance. The working strategy was to propose a real-life problem in which the

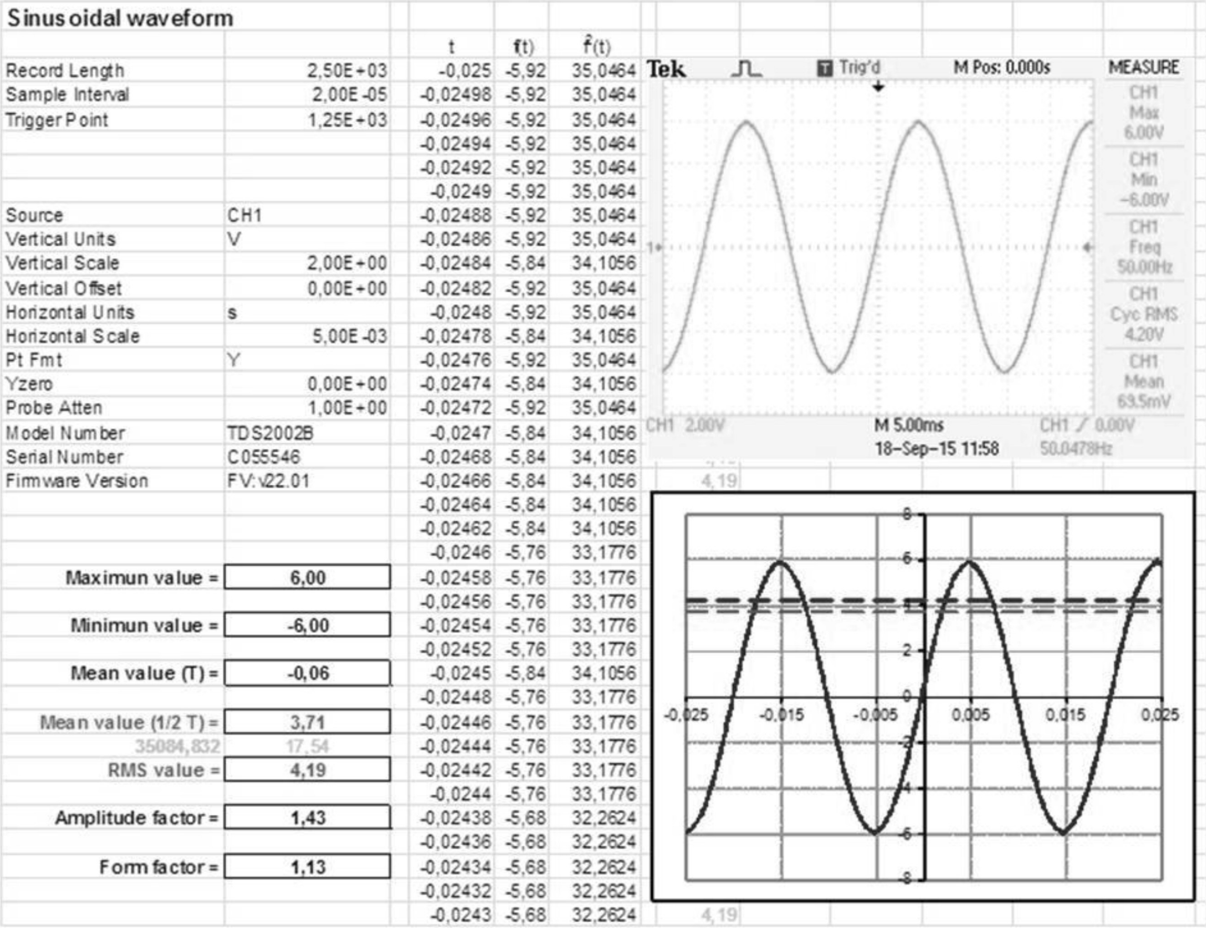
Table 1. Summary of Physics/Mathematics activities.

Activity 1. Newton's law of cooling	**Activity 2. Willard Libby's Carbon-14 dating method**
The dissection room of a medical examiner remains cool at a constant temperature of 5°C. While he was performing the autopsy of a murder victim, the medical examiner himself was killed. The assistant medical examiner discovered the body at a temperature of 23°C at 10 am. At 12 am, the temperature was 17°C. Assuming that the medical examiner's normal temperature was 37°C, what time was he killed?	A humanoid skull was found in a cave in South Africa near the remains of a campfire. Archaeologists believe that the age of the skull is equal to the campfire's age. It has been established that only 2% of the original amount of Carbon-14 is in the wood burned in the fire. Calculate the approximate age of the skull.
Activity 3. Malthusian growth model	**Activity 4. Tacoma Narrows bridge**
A student carrying a flu virus comes back to an isolated university campus with 1000 students. After 4 days, there are 50 infected students. If it is assumed that the speed of virus propagation is proportional to the number of infected students, how many infected students will there be after 6 days?	Search for information about the Tacoma Narrows bridge crash in 1940. Analyze the phenomenon of mechanical resonance and give an explanation about the reason why the bridge crashed.
Mathematics skills to be worked	**Physics skills to be worked**
Dependent variable Independent variable Proportionality Continuous function Concept of derivative as exchange rate Concept of integral Analytical solution Extract information from the solution depending on the problem under study Graphical interpretation of the results Use of mathematical software	Physical dimension Temperature Heating/cooling Thermal equilibrium Radioactive isotopes Half-life Energy Vibrations and waves

students had to identify the affecting parameters and search for information on the Internet. With the help of their high-school teacher and the monitoring of the university teacher, they attempted to solve the questions by themselves. The four proposed activities are summarized in Table 1.

In the field of Technical Drawing an activity about the Diedric System was proposed. The students had to identify the representation of points, straight lines, and planes and solve some easy exercises of increasing difficulty. Afterwards, the exercises were solved with the help of the university teacher in a face-to-face session at the university lab. In the field of Electricity, the students worked in the university lab with analog and digital measurement equipment to analyze different waveforms (square, triangular, and sinusoidal), obtain the characteristic parameters of the wave, learn to make electrical measures, identify the physical magnitudes involved, and graphically represent the results. The activity was divided into four parts: (1) learning the definitions of the main concepts related to waveforms: AC, frequency, symmetry, maximum and minimum values, rising and falling edges, mean value, rms value, amplitude factor, and form factor; (2) measuring a voltage waveform provided by a waveform generator and comparing the results obtained with the ones provided by the theoretical model; (3) measuring the real waveform generated by three different electrical devices (high pressure sodium lamp, compact fluorescent lamp, and computer); and (4) calculating the characteristic parameters of the waveform using a spreadsheet to insert the data captured during the exercise. In this activity, the students became familiar with the use of real laboratory material, practiced with real electrical devices and made theoretical and practical calculations of the main physical magnitudes involved in the use of electricity. Fig. 2 shows the results of one of these activities presented by the students.

5. Final assessment: at the end of the academic year, the entire experience was evaluated. The evaluation consisted of re-assessment of the students with new tests similar to those at the beginning of the year, a survey of the high-school teachers, and a survey of the peer-mentors. The two surveys of high-school students and teachers were put into relation with the initial objectives of the project: increasing the interest of students in engineering degrees, and their knowledge, skills and attitudes to face engineering degrees. The final assessment was designed and validated in the same way that the first one, and the teachers of first course were asked to check whether the test had similar difficulty than the first one or not. Some exam-



Sinusoidal waveform		t	f(t)	$\hat{f}$(t)
Record Length	2,50E+03	-0,025	-5,92	35,0464
Sample Interval	2,00E-05	-0,02498	-5,92	35,0464
Trigger Point	1,25E+03	-0,02496	-5,92	35,0464
		-0,02494	-5,92	35,0464
		-0,02492	-5,92	35,0464
		-0,0249	-5,92	35,0464
Source	CH1	-0,02488	-5,92	35,0464
Vertical Units	V	-0,02486	-5,92	35,0464
Vertical Scale	2,00E+00	-0,02484	-5,84	34,1056
Vertical Offset	0,00E+00	-0,02482	-5,92	35,0464
Horizontal Units	s	-0,0248	-5,92	35,0464
Horizontal Scale	5,00E-03	-0,02478	-5,84	34,1056
Pt Fmt	Y	-0,02476	-5,92	35,0464
Yzero	0,00E+00	-0,02474	-5,84	34,1056
Probe Atten	1,00E+00	-0,02472	-5,92	35,0464
Model Number	TDS2002B	-0,0247	-5,84	34,1056
Serial Number	C055546	-0,02468	-5,84	34,1056
Firmware Version	FV:v22.01	-0,02466	-5,84	34,1056
		-0,02464	-5,84	34,1056
		-0,02462	-5,84	34,1056
		-0,0246	-5,76	33,1776
Maximun value =	6,00	-0,02458	-5,76	33,1776
		-0,02456	-5,76	33,1776
Minimun value =	-6,00	-0,02454	-5,76	33,1776
		-0,02452	-5,76	33,1776
Mean value (T) =	-0,06	-0,0245	-5,84	34,1056
		-0,02448	-5,76	33,1776
Mean value (1/2 T) =	3,71	-0,02446	-5,76	33,1776
35084,832	17,54	-0,02444	-5,76	33,1776
RMS value =	4,19	-0,02442	-5,76	33,1776
		-0,0244	-5,76	33,1776
Amplitude factor =	1,43	-0,02438	-5,68	32,2624
		-0,02436	-5,68	32,2624
Form factor =	1,13	-0,02434	-5,68	32,2624
		-0,02432	-5,68	32,2624
		-0,0243	-5,68	32,2624

Fig. 2. Result of electrical measurements activity.

ple of the questions are: (1) If we say that the engine A has more power than the engine B, it means that...: (a) The engine A can do more work than B, (b) The engine B does less work than A in the same time, and (c) The engine A is more robust than B; 2) The parametric equation of the line $(x-1)/3 = y = (2-z)/2$ is: (a) $x = 3t + 1$; $y = t$; $z = t$, (b) $x = t$; $y = t$; $z = 2t + 2$, and (c) $x = 3t + 1$; $y = t$; $z = 2 - 2t$; (3) In the diedric representation system, a plane is represented by: (a) one line, (b) one point, and (c) two lines; (4) The voltage of an electric system...: (a) is a sinusoidal wave, (b) is a constant and (c) is a combination of sinusoidal waves; (5) Choose what of the following names is not a markup language: (a) Javascript, (b) HTML, and (c) XML.

Once the first year ended and the students passed their official examination to enter the university, we looked for students among those who had participated in the experience during the first year who had decided to come to the Polytechnic School and who was admitted. With regard to the year of study, 14 students entered the Polytechnic School from the four partner high schools: 6 from group 1, 4 from group 2, 2 from group 3, and 2 from group 4. The work with the freshmen participating in the study was organized as follows (Fig. 3):

1. The coordinator of the project asked the Polytechnic School to be nominated as a mentor for the 14 students during their first year.
2. The four peer-mentors, now in their fourth and last year of their degree, were recruited again to take part in the project and were assigned to the freshmen of their degree.
3. Under the supervision of the mentor, the peer-mentors worked with the freshmen to introduce them to the university system, give them information on the campus services, and advise them about the best way to follow the most difficult subjects.
4. Throughout the academic year, each freshman maintained his/her continuous relationship with his/her peer-mentor to obtain useful information about university life, seminars, subject bibliographies, information repositories, and any other information they requested. The work of the entire group (tutor, peer-mentors,

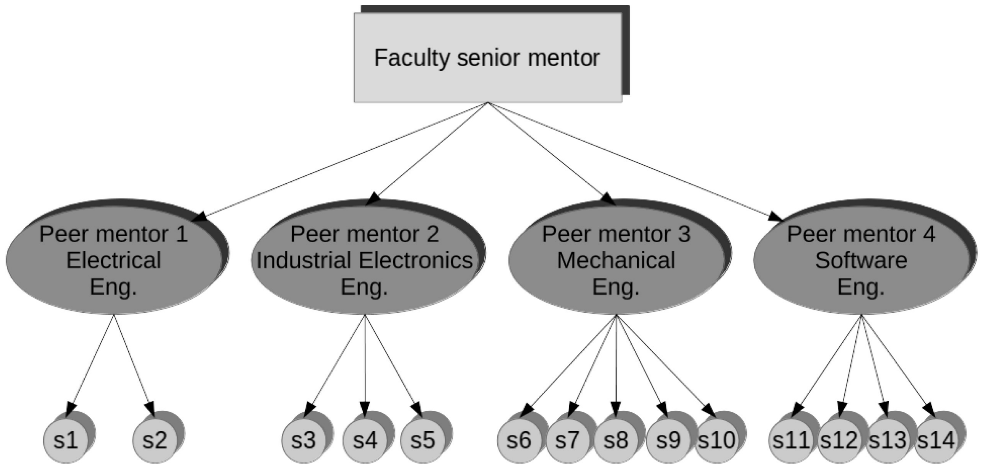


Fig. 3. Hierarchy of mentoring structure.

and freshmen) was structured around three meetings scheduled for the beginning of the year, the end of the first semester, and halfway through the second semester. The content of each meeting is related below.

(a) First meeting: this initial contact of the entire working group consisted of an introduction of the components and presentation of the degrees, structure, first-year content, complementary activities, and main experiences of the peer-mentors in relation to the course development. The freshmen were encouraged to follow all of the programmed activities in each of the subjects and to ask for help from the peer-mentors and senior mentor as needed. Finally, a new meeting was scheduled before the end of the first semester.
(b) Second meeting: at the end of the first semester, the students already had enough knowledge about the structure and general functioning of the university, and they presented some doubts and even some complaints about the development of the course. Specifically, they asked for a more precise relationship between the subject programs and their real development during the course, and they complained about the high number of partial exams and the lack of coordination between subjects. In contrast, however, they recognized the work of some teachers in the first year. This information was communicated to the faculty direction to be taken into account in the quality assurance plan of the degree. Finally, all students were encouraged to follow the individual tutorial sessions in the subjects they found more difficult.
(c) Third meeting: the final meeting took place in the middle of the second semester. Its main aim was to analyze the situation of each student before the final exams. The general impression of the entire group was that the experience had been useful and that the expected final results were good. The session focused on the plan for the second year. The students were advised to follow the module of 60 credits per year and not to take more subjects than they could manage. The students' requested for the organization of the timetable was the late shift for the second year and the early shift for the first year.

5. At the end of the year, the academic performance of the freshmen participating in the project was analyzed in comparison with the other students of the same entrance cohort.
6. As an additional assessment of the success of the project, the retention ratio as well as the number of credits passed by participating students was compared with the rest of the entrance cohort at the end of the second year.

3. Analysis of data and results of the program

3.1 Initial assessment of high-schools students

All students were evaluated during the first month of the course with the same initial test, which consisted of 20 questions about basic concepts of Physics (5), Mathematics (6), Technical Drawing (4), Electricity (2), and Informatics (3). The results of these tests are summarized in Table 2, and the distribution of the result frequencies appear in Fig. 4.

The general results of the assessment were poor. In fact, only students from High School 2 had a

Table 2. Results of the students' initial assessment (0–100%)

High School 1		**High School 2**	
Máx	62%	**Máx**	71%
Mín	4%	**Mín**	33%
Stdev	16.27%	**Stdev**	11.59%
n	20	**n**	10
Mean	34.38%	**Mean**	55.00%
High School 3		**High School 4**	
Máx	92%	**Máx**	58%
Mín	0.00%	**Mín**	18%
Stdev	24.82%	**Stdev**	13.91%
n	24	**n**	12
Mean	45.07%	**Mean**	39.88%

Table 3. Results of the students' final assessment (0–100%)

High School 1		**High School 2**	
Máx	81%	**Máx**	82%
Mín	14%	**Mín**	39%
Stdev	17.24%	**Stdev**	12.89%
n	20	**n**	10
Mean	43.43%	**Mean**	64.50%
High School 3		**High School 4**	
Máx	97%	**Máx**	76%
Mín	15%	**Mín**	24%
Stdev	25.20%	**Stdev**	19.78%
n	24	**n**	12
Mean	57.21%	**Mean**	51.90%

mean mark above 50%, so the level of the students' knowledge in these subjects needed to be reinforced during the last year of high school to obtain better entrance scores to the university. Most of the failed answers were in the subjects of Physics, Mathematics, Technical Drawing and Electricity, whereas the questions about Informatics had acceptable results.

3.2 Final assessment of the first-year experience

Once the first year ended, all the students were reassessed with a new test similar to the initial assessment. The results of the final assessment can be seen in Table 3 and Fig. 5. All the students were found to have improved their knowledge and skills in the basic subjects that they worked on during the academic year. Specifically, the mean marks increased in the four high schools as well as the maximum and minimum marks. The t-test (significance level $\alpha = 0.05$) in Table 4 shows that all the final results were better than the initial ones with statistically significant differences. Additionally, both the students group and the high-school teachers group were asked about how useful they found the project and how much it changed the students' opinions and attitudes about university engineering studies (Tables 5 and 6). The results of these surveys were favorable toward the project, but the opinions of the role of peer mentors and the improvements in students' knowledge were particularly notable.

3.3 Academic results of freshmen

Once the enrollment period of the following year had finished, the university team identified which of the students participating in the project had decided to enroll in one of the degrees offered by the Polytechnic School. The result was that 14 students of the initial 66 decided to enroll in the Polytechnic School: 6 from High School 1; 4 from the High School 2; 2 from High School 3; and 2 from High

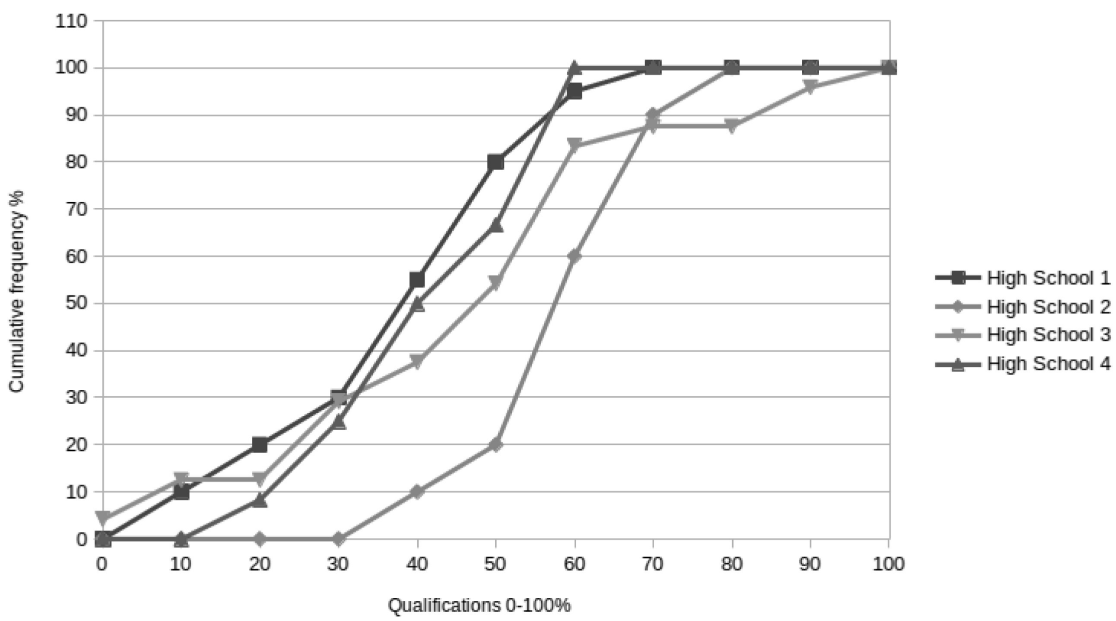


Fig. 4. Comparison of the initial assessment results in the four high schools.

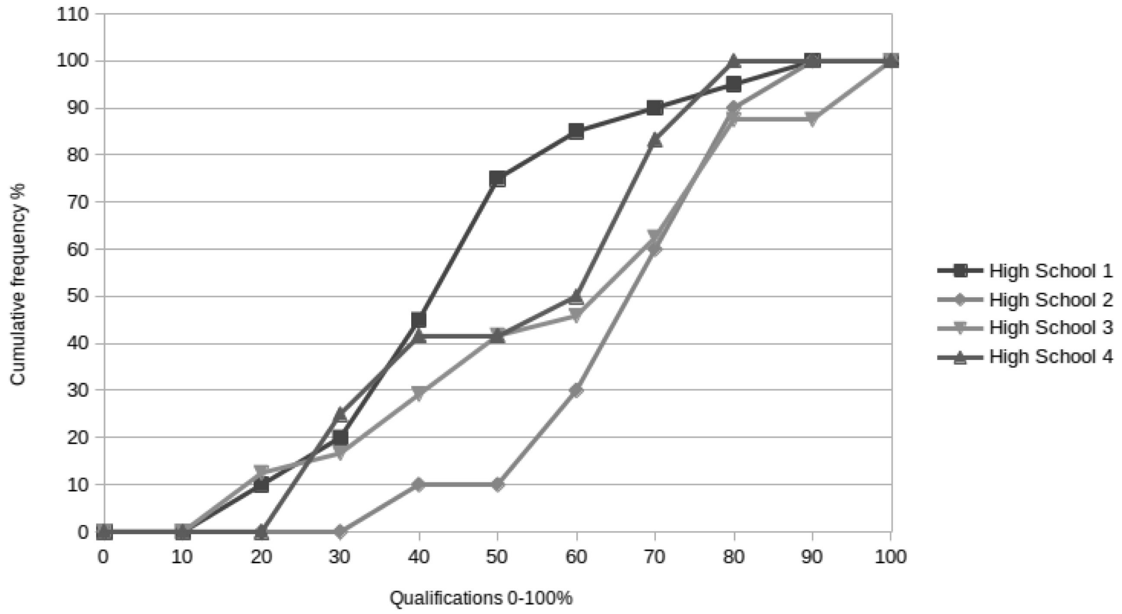


Fig. 5. Comparison of the final assessment results in the four high schools.

Table 4. Results of t-test of initial and final assessments.

	Initial			Final					
	Mean %	**Var.**	**N**	**Mean %**	**Var.**	**N**	**t**	**t_c**	**p**
High School 1	34.38	264.76	20	43.43	297.06	20	–1.707	1.686	0.048
High School 2	55.00	134.26	10	64.51	165.11	10	–1.737	1.734	0.050
High School 3	45.07	616.25	24	57.21	636.57	24	–1.680	1.679	0.050
High School 4	39.88	169.29	12	51.90	388.92	12	–1.762	1.729	0.047
Global	42.39	390.72	66	53.17	456.06	66	–3.010	1.657	0.002

Table 5. Students' survey about the benefits of the project.

Mark from 1 (less) to 5 (more) if you agree with the following sentences:	High School 1		High School 2		High School 3		High School 4	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
My opinion about engineering degrees is better after the project.	4.2	0.77	3.6	0.52	4.0	0.88	3.8	0.58
My interest in enrolling in an engineering degree has increased after the project.	4.4	0.93	4.7	0.48	4.3	0.52	4.3	0.49
My level of knowledge about basic subjects of engineering have increased after the project.	4.3	0.66	3.7	0.48	4.3	0.52	4.0	0.63
My information analysis skills are better after the project.	3.7	0.86	4.3	0.48	3.7	1.25	3.5	0.90
My problem solving skills are better after the project.	3.3	0.66	4.0	0.00	3.0	1.45	3.7	0.78
My active learning skills are better after the project.	3.3	0.73	3.7	0.48	3.3	1.71	4.0	0.43
The participation of peer mentors is useful to eliminate psychological barriers about my entrance in the university.	4.6	0.51	5.0	0.00	4.7	0.48	4.3	0.78
My relationship with my peer mentor has helped me to choose an engineering degree.	3.7	0.81	4.7	0.48	4.3	0.97	4.3	0.65
It would be interesting for university students to visit my high school periodically in the future to share their experience about the engineering degrees.	4.6	0.50	5.0	0.00	4.0	1.45	4.4	0.51

School 4. Five of them chose Mechanical Engineering, 4 chose Software Engineering, 3 chose Industrial Electronics Engineering, and 2 chose Electrical Engineering. The 14 students were distributed between the same 4 peer-mentors of the previous year, one for each degree of election and all of them under the supervision and coordination of the project's responsible.

Table 6. Teachers' survey about the benefits of the project

Mark from 1 (less) to 5 (more) if you agree with the following sentences:	**High School 1**	**High School 2**	**High School 3**	**High School 4**
Students' opinion of engineering degrees is better after the project.	3	4	4	4
Students' interest in enrolling in an engineering degree has increased after the project.	3	4	5	4
Students' level of knowledge about basic subjects of engineering has increased after the project.	4	4	4	4
Students' information analysis skills are better after the project.	4	3	3	3
Students' problem solving skills are better after the project.	4	3	3	4
Students' active learning skills are better after the project.	4	3	3	4
The participation of peer mentors is useful to eliminate psychological barriers about students' entrance in the university.	5	3	4	5
Students' relationship with their peer mentor has helped them to choose an engineering degree.	4	3	4	4
It would be interesting for university students to visit my high school periodically in the future to share their experience about the engineering degrees.	5	5	5	5

At the end of the year, the marks of the group were analyzed in comparison with the rest of the students in the same entrance cohort (14 participating students and 382 non-participating students), and the peer-mentors were asked about their experience during the two-year experience. The retention rate of the participating students was analyzed at the beginning of the second year in comparison with their entrance cohort. Moreover, the global success of participating and non-participating students was analyzed at the end of the second year.

Figure 6 shows the marks distribution for all the subjects of the first course (from 0 to 10), of all the students enrolled in the Polytechnic School for the first time in the 2013–2014 course, and comparing participating and non-participating students. The figure shows that the marks obtained by participating students were substantially better than those obtained by non-participating students. Fig. 7 shows the percentage distribution of passes, fails, and drops. It is especially striking that the percentage of drops among non-participating students was almost 50%, whereas the percentage of passes of participating students was approximately 66%. Table 7 shows the results of the t-test (significance level $\alpha = 0.05$) of the means comparison of all the assessments conducted during the academic year and the first and the second convocation separately. In all cases, the results of the participating students were significantly better than the results of the non-

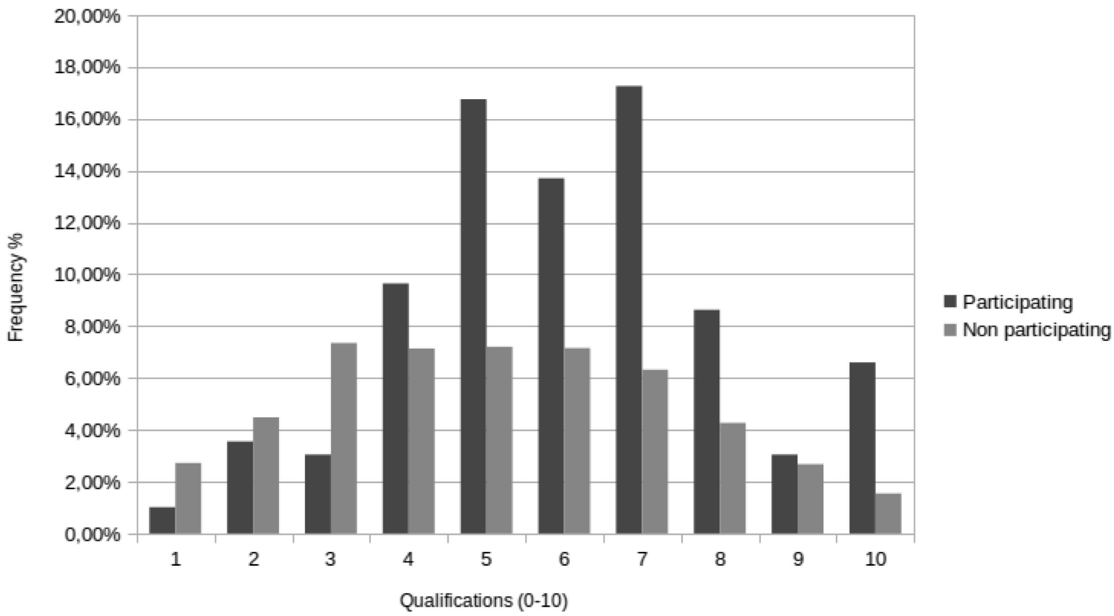


Fig. 6. Global marks distribution of participating and non-participating students.

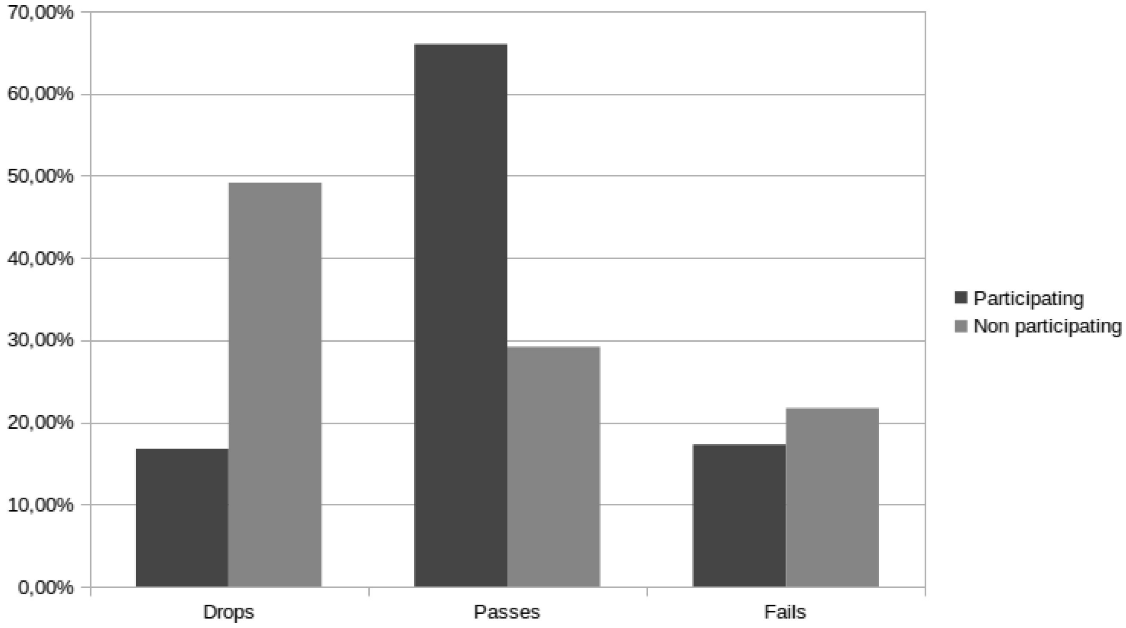


Fig. 7. Global distribution of passes, fails and drops of participating and non-participating students.

Table 7. Results of t-test of participating and non-participating students' marks results

	Participating			**Non-participating**					
	Mean	**Var.**	**N**	**Mean**	**Var.**	**N**	**t**	t_c	**p**
Combined results	5.77	4.39	164	4.79	5.23	3121	5.82	1.65	$1.30e^{-08}$
First convocation	5.80	4.98	119	4.83	5.61	2218	4.60	1.66	$4.83e^{-06}$
Second convocation	5.68	2.88	45	4.68	4.30	903	3.82	1.68	$1.81e^{-04}$

Table 8. Peer-mentors' survey

Mark from 1 (less) to 5 (more) if you agree with the following sentences:	**Peer-mentor 1**	**Peer-mentor 2**	**Peer-mentor 3**	**Peer-mentor 4**
Students who have been assigned to me had very little knowledge of the Polytechnic School and its degrees.	4	4	3	2
The most frequent consults along the course have been about:				
Internal organization of the school and the university.	4	3	4	2
Continuous advice about technical subjects.	4	5	4	5
The freshmen have faced their first year confidently and without fear.	5	5	4	5
I think that my intervention during the course has been useful and has had a favorable effect on the academic results of my mentees.	5	3	4	5
The learning skills of my mentees have improved during the first year.	4	4	4	5

participating students. Finally, Table 8 shows the peer-mentors' perceptions of the usefulness of their mentoring work during the year, which substantially coincided with the opinions of the students and teachers.

Finally, the number of students who enrolled the second year, from the entrance cohort of 2013–2014, resulted in 14 students remaining of the 14 original students among the students who participated in the project, whereas there were 280 remaining students among the non-participating from an initial total of 372 (75.27%). The mean of the total credits passed during the first two years by the students participating in the project was 87.49, whereas the mean of the credits passed by non-participating students was 61.37. Table 9 shows the t-test results of the means comparison with a clear significant difference in favor of participating students. Fig. 8 shows the distribution of credits passed during the two years by the two groups.

Table 9. Results of t-test of passed credits of participating and non-participating students after the second year

Participating			Non-participating					
Mean	**Var.**	**N**	**Mean**	**Var.**	**N**	**t**	t_c	**p**
87.49	596.57	14	61.37	1120.82	269	3.81	1.75	$7.96e^{-04}$

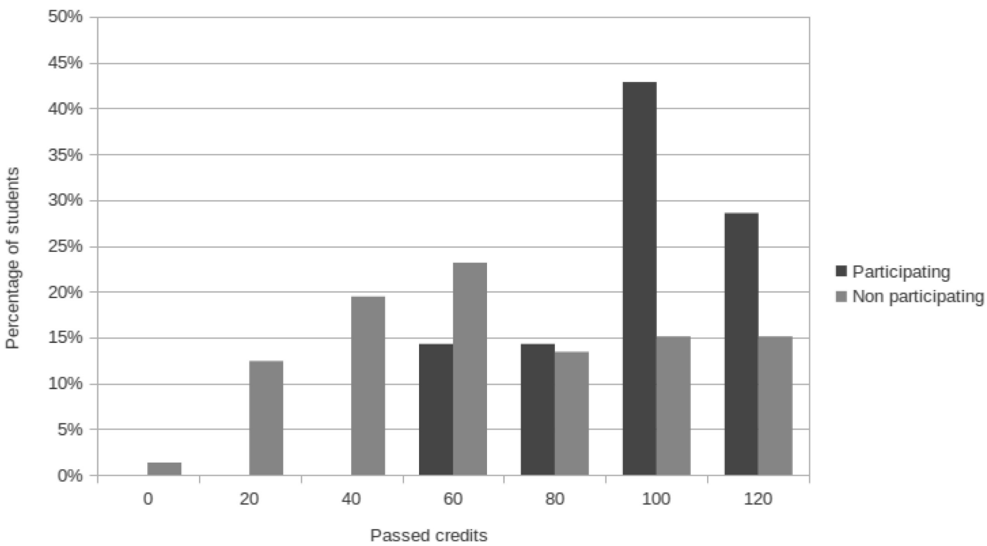


Fig. 8. Distribution of passed credits among students after the second year.

4. Discussion

According with other similar studies related in the literature, the use of activities related to engineering during the last year of high-school in collaboration between high-school and university teachers, has shown to be useful to increase the interest of students in enrolling in engineering degrees. In this sense, this practice has different benefits which are, not only improving knowledge of basic concepts needed to entrance in engineering degrees, but losing psychological barriers about the profession of engineering in general, to improve students' self-confidence about their skills and attitudes, and to increase the recruitment in engineering degrees. Furthermore, other important concern of university authorities and staff must be students retention, due to the generalized high attrition rate. A number of mentoring programs have been developed by universities to help the students, and specially freshmen, to feel themselves as part of the institution and not as simple visitants. In this way, hierarchical mentoring programs, peer mentoring programs, and other variants have proved to be useful to increase retention and success rates of freshmen.

The original contributions of this work are: the personalized design of activities once the students have been previously assessed about basic concepts needed to enter engineering degrees; the combined use of activities during the last year of high-school with a peer mentoring program; and monitoring the performance of first year students by means of a mentoring and peer mentoring program. The benefits of this combined strategy are clear: high-school students show considerable improvements of their basic skills to face their university entrance and with very low impact on the normal development of the course; their attitude in front of engineering degrees and engineering as a profession is better after their contact with engineering teachers and students and after being correctly informed about engineering curricula, the structure of the School and general university services; and freshmen participating in the project show better academic performance and retention than non participating students.

However, the experience has some limitations. Firstly, it is not possible to reach all the potential applicants due to staff and spatial limitations, so the efforts have to be concentrated on a few high-schools of the area. Even more, it would be difficult to maintain a program as the one described for a long period of time without a proper recognition of the effort from high-school and university teachers in terms of hours of laboral dedication or, in other words, without the establishment of an official collaboration program between high-schools and university.

Anyway, the results of participating students compared to non participating ones and the opinion of students and teachers after the experience stimulate to continue with these kinds of projects to put engineering students in better position to face the first year of the degree, when it is known that they find the major difficulties. Moreover, the exigency in STEM subjects in pre-university levels as well as the transition from high-school to university should be reconsidered to avoid the high rates of failure and attrition during the first year.

5. Conclusions

A successful two-year program combining collaboration with high schools and mentoring of freshmen was conducted during the 2012–2013 and 2013–2014 academic years. The main goal of the project was to improve the conditions of freshmen entering engineering degrees and to decrease failure during the first year. The strategy required the combined intervention of high-school teachers, university teachers and university students working together for two years.

The results of these activities were not only an objective improvement of the students' knowledge and skills but also a substantial improvement in their opinions about the engineering degrees and their psychological attitude about their university entrance. It is especially remarkable that in the four collaborating high schools, the results of the students' assessment after the activities were conducted were significantly better than before. Moreover, the subjective opinions of both students and high-school teachers were generally favorable to the project. For example, the students recognized that the project improved not only their knowledge of basic engineering concepts but also their attitude and their opinion about entering engineering degrees.

At the end of the first year of the experience, the students who decided to study engineering at the university and who were admitted were identified. In the second phase of the project, each student was assigned to a faculty senior mentor and a peer-mentor in a pyramidal structure. With this strategy, the students were integrated into the general academic structure and obtained better information and advice about the subjects, teachers, resources at their disposal, and tutoring programs from the first day. The results obtained by the participating students were substantially better than those obtained by the non-participating students in all senses: marks distribution; number of passes, drops, and fails; retention rate in the second year; and number of credits passed. Moreover, the peer-mentor students noted that their labor had been useful for the freshmen during their first year.

In general, the entire experience was found to be useful for eliminating students' psychological barriers when entering university engineering studies. Students' performance was much better than usual during the first year. In the near future, an integral program for the entire school should be put into practice. To achieve this goal, the collaboration of the entire faculty must be requested, and a complete and coordinated program should be organized by the directive staff. This type of mentoring program should be integrated into the normal duties of the faculty and recognized as a normal teaching labor, even in terms of dedicated hours. The benefits of the peer-mentoring work for the peer-mentors themselves should also be evaluated in terms of an analysis of their academic performance and should be recognized in terms of dedicated hours.

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