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A NEW LEARNING EXPERIENCE: VOLUNTARY PREPARATORY COURSE FOR THE BACHELOR'S DEGREE IN ENGINEERING

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Abstract

This paper reports on a new experience carried out at school associated with the Technical University of Catalonia, Universitat Politècnica de Catalunya (UPC) in September 2010. The aim is to describe the organization, funding and results of a preparatory course in Physics for a bachelor's degree in Engineering. We assess the students' opinions about the experience and whether it should be repeated. We also analyze the profile of the students who access this School, estimating their initial knowledge of physics. The results obtained provide solid evidence that 70% of new students coming from Vocational Education Schools do not meet the required minimums.

Keywords **-** Initial knowledge, levelling, moodle.

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1 INTRODUCTION

The Barcelona College of Industrial Engineering, Escola d'Enginyeria Tècnica Industrial de Barcelona (EUETIB), is associated with the Technical University of Catalonia, Universitat Politècnica de Catalunya (UPC), and has ample experience in training industrial engineers. It currently awards Bachelor's degrees in the following fields: Electrical Engineering, Industrial Chemistry; Industrial Electronics, Mechanical Engineering, Biomedical Engineering and Energy Engineering. During the 2009-2010 academic year, new study plans were implemented in all six degrees. In these new plans, there are two common years in which general basic subjects such as Physics, Chemistry and Mathematics are scheduled. The first-year subjects are part of a studies block called the "Initial Phase" that the students have to pass within a maximum of two years in order to ensure that they can continue their studies.

Every year, around 600 new students enter EUETIB. We often observe some differences in the level of the students, and it seems that year after year, these differences are increasing. The difference in level among new students is especially worrisome precisely in these basic subjects. Even though the Physics teachers have already noticed these differences for years, we had never quantified them, nor had we carried out a thorough study to find the origin of the problem. These are the main reasons that motivated us in the 2009-2010 academic year to consider the possibility of conducting a study to assess the students' prior knowledge, with the aim of developing strategies and resources to solve this problem. In the first section of this report, we present the results of this study.

Simultaneous to the implementation of the new Bachelor's Degrees in the Catalonian Universities, the autonomous Government of Catalonia, the Generalitat de Catalunya, started the program EnginyCAT [1]. EnginyCAT was created as an initiative by the Secretariat of Universities and Research, implemented through the Directorate General of Universities, which had the mission of fostering the university study of science, technology and engineering. One of the strategies of this program was the co-funding of scholarships so that students in the last years of their degree studies acted as mentors to first year students. It is important to note that the difficulties that students find in their first year at University, in many cases, lead them to abandon their

studies. Another advantage is that those students acting as mentors acquire leadership and communication skills. At EUETIB, teachers from the departments of Physics, Mathematics and Chemistry applauded the initiative and did everything possible to use this resource for our subjects. Since 2009, there have been 6 grants for students in their last year of studies to act as mentors for eight months a year to help students registered in Physics I and PhysicsII, both subjects in the first year of the degree program. This allowed us to offer the students two hours of free review classes per week, in small groups of 8 to 10 students, during the four months of the semester. The purpose of these classes is to reinforce the topics covered in ordinary class sessions through problem-solving exercises. In the 2009-2010 edition of the EnginyCAT program, we had approximately 190 students attending the Physics review classes. The high degree of involvement on the part of the students who acted as mentors and the results of the satisfaction surveys that were administered to the new students participating in the program confirm the success of this initiative.

The good results obtained with the EnginyCAT program, together with the confirmation of the educational gaps that an important group of the new students had, made us consider the possibility of organizing an introductory course to be taken before students started the ordinary classes. This was the "preEnginycCAT-Physics" course, which is precisely the subject of the present report.

The objective of the "preEnginyCAT-Physics" course was to review very basic concepts of physics that the students should know before starting their studies. The first edition of this course took place on September 1-3 and 6-7, 2010. The course was completely free and voluntary for the registered students. During these 5 days, the students received 2 hours of Physics lessons per day. On the same days, another free course with the same philosophy, "preEnginyCAT-Mathematics", was also scheduled.

The present paper is organized as follows: as already mentioned, in Section 2 we present the results of the study on the initial basic knowledge level; in Section 3, we describe the organization of the "preEnginycCAT-Physics" course; the evaluation of the results is presented in Section 4 and finally, the conclusions are drawn in section 5.

2 ASSESSING THE STUDENTS' PRIOR KNOWLEDGE

On the first day of the 2009-2010 academic year, the Physics teachers asked all the students to take a prior knowledge test. The test was an assessment intended to measure the physics and mathematics background of the new students entering the university. The test was anonymous, but the students were asked to indicate their pathway to accessing the university and their previous studies, i.e., whether they came from Secondary School or from Vocational Education. They were also asked whether they intended to work while studying. The test consisted of 10 multiple-choice questions with 4 alternatives and only one correct answer, as shown in Table 1.

475 students completed the test: 72% came from Secondary School, 20% from Vocational Education, 8% from other backgrounds and 20% stated that they were working.

The right column of Table 1 shows the percentage of correct answers for each question. The worst-answered questions were numbers 6, 10 and 2. Among all the questions, the only questions that required solving a system of two linear equations were numbers 6 and 2. Besides a basic knowledge of physics, these questions also required a working knowledge of Algebra. In addition, questions involving derivatives and integrals (numbers 4 and 5) were only answered correctly by 60% of the participants. This fact strongly indicates that a significant number of students arriving at university have a weak knowledge of Calculus. The remaining straightforward questions were, in general, answered correctly.

The test was scored as the number of correct answers with a penalty for guessing of 0.25 points. The overall distribution of the final score is shown in Figure 1. Such results imply that:

- 74 % of the new students passed the test

Based on their previous studies, the score distribution indicates that:

- 83% of the new students coming from Secondary School passed the test
- only 30% of the new students coming from Vocational Education passed the test

It can be observed that, in the case of students coming from Vocational Education, the probability of failing the test reaches 70%. This result can be added to recently published studies showing that these differences still

persist throughout the "Initial Phase" of the curricular block (López López, Buenestado Caballero, Pérez Gracia, García-Alzórriz Pardo, Torres Cámara & Martínez, 2010).

Taking into account the level of the questions, which in some cases were quite basic, we find the low percentage of students coming from Vocational Education who passed the test to be especially troubling.

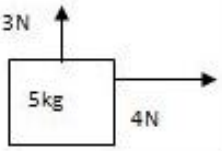
1.- The area of a circle with a radius R is indicated by the expression: a. $2\pi R$ b. πR^2 c. $4/3\ \pi R^2$ d. $4\pi R^2$	80%
2.- If two forces are simultaneously applied to a 5 kg body of mass as shown in the figure, its acceleration will be: a. 5 m/s² b. 1 m/s² c. 5/7 m/s² d. 7/5 m/s² 	40%
3.- The solution of the equation $x+2/3=5$ is: a. 13/3 b. 7/3 c. 3/5 d. 10/3	91%
4.- Determine the derivative $y'(x)$ of the function $y(x)=\sin(3x^2)$ a. $y'(x)=6x\cos(x)$ b. $y'(x)=-6x^2\cos(3x^2)$ c. $y'(x)=-6x\sin(3x^2)\cos(x)$ d. $y'(x)=6x\cos(3x^2)$	65%
5.- The result of the integral $\int(3x^2+2)dx$ is: a. x^3+2x+C b. $3x^3+2x+C$ c. $6x+C$ d. $3/2\,x^3+2x+C$	61%
6.- We throw a ball against the floor, from a height of $h = 5\text{m}$ and with an initial vertical speed of $v = 4\text{m/s}$. If we consider there is no loss of energy when it bounces, what height will it reach? a. 4.6 m b. It can't be determined. c. 5 m d. 5.8 m	29%
7.- A bullet travels along a track as shown in the figure. The track lies on a horizontal table. Which of the following trajectories does the bullet follow once it leaves the guide? a. trajectory A b. trajectory B c. trajectory C d. none of the above 	70%
8.- A ball thrown up in the air by a girl on a train moving at constant speed will fall: a. in the girl's hand b. behind the girl c. in front of the girl d. It can't be determined.	73%
9.- Energy is a very important concept in physics, and in other subjects... Determine which of the following expressions does NOT correspond to energy: a. $\frac{1}{2}mv^2$ b. mv c. mgh d. $\frac{1}{2}kx^2$	78%
10.- Which physical quantity is conserved in any type of collision? a. kinetic energy, E_c b. momentum, **p** c. energy and momentum d. neither energy nor momentum	34%

Table 1. Multiple choice knowledge test. The right column shows the success rate

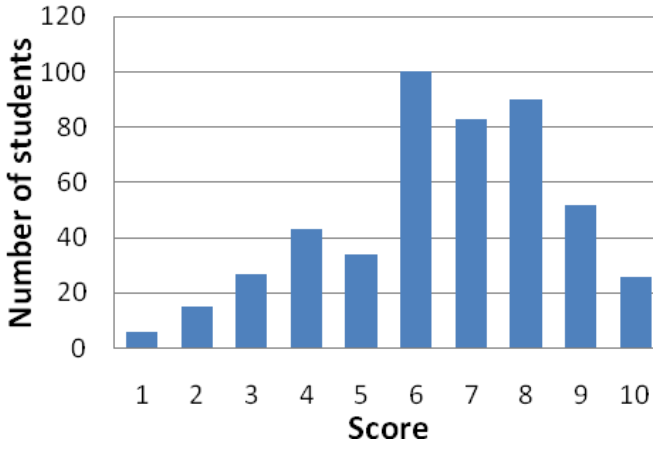


Fig.1. Score distribution of the prior knowledge test

3 COURSE ORGANIZATION

Looking at the results of the prior knowledge test, it seemed important to do something to help the students that access our school overcome their educational gaps. It is important to note that paradoxically, all the students who failed the prior knowledge test had achieved the required score to enter the different degree courses of EUETIB. In September 2010, the same score, 5.76 out of 10, was required for all six degree programs, and was the fifth highest score required for any of the 42 degrees offered by the UPC in the academic year 2009-10 (Generalitat de Catalunya, 2009). We also considered that, in terms of scientific abilities, the PISA report of 2006 placed Catalonia between Croatia and Latvia (tied with Iceland), with a significantly lower score than the OCDE average (Consell Superior d'Avaluació del Sistema Educatiu, Generalitat de Catalunya, 2008). The need for preparatory training for university students is also supported by different studies (Bohigas Janoher, Estradé Sobrepere, Madrueño Sicart & Porquer Seguí, 2008).

After evaluating with the college department heads what initiatives we could carry out and what kind of material and personal resources might be available, we offered the preparatory course "preEnginyCAT-Physics" in September 2010, before the academic year started. It is important to note that the preparatory course lasted only 10 hours and, unlike other courses, students received no credits for it. It is worth mentioning that other Catalonian universities organize review courses with the aim of helping students to reach a suitable level in the subjects of their plan of studies. These courses are usually scheduled before the start of the academic course and generally give the option to earn open credits (Univeristat Autònoma de Barcelona, 2011). This was not the case of either the UPC or the EUETIB.

The students eligible for the preEnginyCAT course where those who had registered at the school in July (approximately 500). The 6 Physics EnginyCAT mentors who had experience as mentors in the 2009-2010 academic year gave the classes. 90 places were offered, in 6 groups of 15 students per group. Each group met for 2 hours per day, scheduled either form 10 am-12 pm, 12-2pm or 4-6pm. The professors who coordinated the Physics-I module organised the classes programme and gave the necessary course material to both the mentors and the students.

The course was announced on the bulletin board and on the ATENEA virtual campus (Moodle), and the students were also informed about the course upon registration. Once the registration of new students was closed, the preEnginyCAT module was created in ATENEA, where the list of students was posted. When the students entered the virtual class, they could access an on-line moodle test, a form to sign-up for it and all of the course information, i.e., the course material.

The aim of the online-test was to give new students a self-evaluation tool to test their initial knowledge, which would allow them to decide whether they needed to join the preEnginyCAT course. The multiple-choice test, similar to the one we previously presented, consisted of 6 basic Physics questions that had to be answered in less than 15 minutes and on the first try.

43% of the 512 students who matriculated in July took the online-test. The average score was 4.67 out of 10 (when the incorrect answers were not penalized) and 2.50 with a penalization of 33% for each question. Figure 2 shows the number of students who answered a specific number of questions correctly.

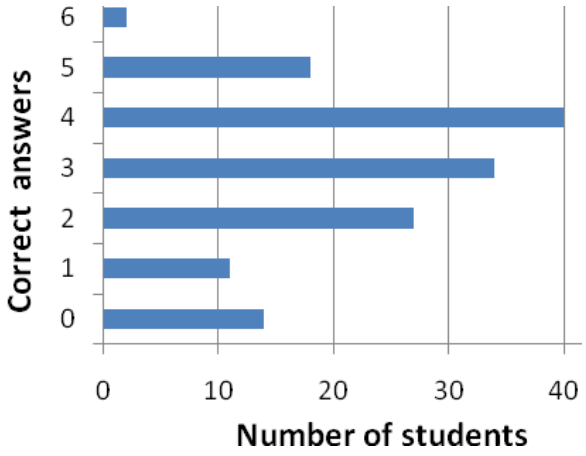


Fig.2. Number of correct answers given by a certain number of students on the on-line test

As already mentioned, students could sign up for the course on-line using ATENEA. The 90 available places were filled within a fortnight, in chronological order in which the applications were received (on a first come, first served basis).

The course contents were based on Kinematics and all the material was provided to mentors by the coordinators of the Physics I course. The first section, devoted to One-Dimensional Movement, allowed us to revise basic concepts in Kinematics, as well as the calculation of simple derivates and integrals. The second section, concerning Two and Three-Dimensional Movement, gave us the chance to carry out a good revision of vector calculus.

The course material needed by the students and mentors was posted on ATENEA and organized as follows:

Section 1. One-Dimensional Movement: a summary of theory, with problem solving exercises for the students. A copy of the exercises with their solutions was also provided to the mentors.

Section 2. Two- and Three-Dimensional Movement: a summary of theory, with problem solving exercises for the students. A copy of the exercises with their solutions was also provided the mentors.

Additional materials: summaries of mathematical formulae (areas, volumes, trigonometry, exponential and logarithmic functions, integrals and derivatives)

Two class sessions were dedicated to each section. In each session, the mentor gave a brief summary of the theory, provided some examples and proposed exercises to the students, to be solved under their supervision, in addition to homework for the following class session. The last session was dedicated entirely to problem solving.

4 RESULTS AND DISCUSSION

The preEnginyCAT announcement clearly specified the voluntary nature of the course, and that it was completely free of charge, but that, once registered, class attendance was obligatory. The mentors kept a strict attendance record, which is shown in Table 2. There were 6 groups with 15 students per group, and each student had to attend 5 classes, which equals 6 groups x 15 students x 5 days = 450. Overall, there were 34 absences, plus a vacancy. On the first day, two students failed to appear and one was replaced by another student. This resulted in an attendance rate of 91.3% (considering 34+5=39 absences out of 450).

When the course finished, the person in charge of the EUETIB EnginyCAT program gave the students an evaluation survey. The aim of this questionnaire was to assess their opinions about the course contents, the role of the mentors, the classrooms where the course was held, etc. 50 out of 90 students answered the questionnaire. Figure 3 shows the assessment of the course contents. 36% answered that it had clearly helped

them to fill educational gaps (answer a) and 56% felt it helped them to brush up on concepts (answers b and c). Hence, 89% considered the course to be useful. 6% of the students clearly had a level that was superior to the course level (answer d), and one student recognized being incapable of following the course because it was too complicated (answer e).

	9/01/2010	***9/02/2010***	***9/03/2010***	***9/06/2010***	***9/07/2010***	***TOTAL***
Group 1	15	15	15	13	11	69
Group 2	14	12	13	12	11	67
Group 3	14	14	13	14	14	69
Group 4	15	15	15	15	11	71
Group 5	15	15	11	14	13	68
Group 6	15	15	13	12	12	67

Table 2. Attendance at each of the 6 "preEnginyCAT" courses. Number of students

In Table 3 we show the most relevant questions and answers of the questionnaire, where another interesting aspect to note is that 88% of the participants would recommend the course to new students.

1. In relation to the contents studied in the preEnginyCAT sessions, I think that:			
a. It has helped me to understand things I didn't know or I didn't understand well enough in my previous studies			36 %
b. Some things were useful, but I already knew most of the concepts			32 %
c. I think that it was a repetition of concepts that I already knew			24 %
d. It has not been very useful because I knew almost everything			6 %
e. It has not been very useful because I didn't understand anything			2 %
2. My opinion of the student- mentors who taught the preEnginyCAT classes is:			
a. Very positive	b. Positive	c. Neutral	d. Negative
38 %	52 %	10 %	0 %
3. I think that the preEnginyCAT programme... (you may choose more than one answer for this question)			
a. has helped me at the start of my engineering studies			60 %
b. has helped me to realize that I have to make a serious effort to keep up at the university level			31 %
c. has not made any difference in my level			10 %
4. With reference to the preEnginyCAT programme, in general...			
a. I would recommend it to any new EUETIB student			88 %
b. I would neither recommend nor discourage students from taking it			12 %

Table 3. Results of the final evaluation survey

The questionnaire included an open-ended question where we observed interesting contrasts. While a student from a Vocational Education School states: "For people who come from Vocational Education studies, I feel that the physics level of this course is too high", several students coming from Secondary School expressed quite the opposite; for instance, one suggested: "It would be useful to revise more advanced concepts, such as the concepts studied in the last year of high school".

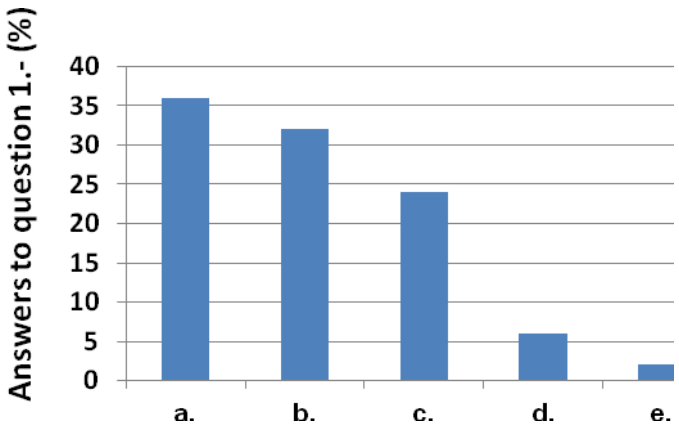


Fig.3. Distribution of answers to question 1

5 CONCLUSIONS

To conclude, we have seen that the preparatory course held at EUETIB in September 2010 attracted lots of interest among students. This is evidenced by the fact that they maintained a course attendance rate of 91.3%, which is much higher than the attendance rate for normal classes, even though the course had no incentive other than knowledge. Moreover, we presume that the preEnginyCAT course has been useful to students, as 88% would recommend it. However, it would also be worth tracking the progress of these students during their first year at the university. We expect that this experience should be repeated, since we believe it is very necessary, especially in cases where students have really different backgrounds before entering university, as is the case at EUETIB.

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