UNIVERSITY PROPAEDEUTIC PHYSICS: ENGINEERING DEGREES EXPERIENCE

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Abstract

In this study we describe and analyze the experience that has been carried out for more than a decade. It has been found that after the specific training, the percentage of students with a low initial level who pass the compulsory subject is like that of students with an adequate initial level. Furthermore, the student perception surveys show their high degree of satisfaction with the training received, as well as with the involvement of teachers and mentors and the learning material provided to them. They especially value face-to-face interaction. Regarding the evolution over this decade, it has been noted that: (a) the percentage of students who need this support is increasing, (b) they are increasingly demanding in the audiovisual quality of the learning material provided to them, (c) reading and writing problems are increasing and, (d) the capacity and time of effective concentration is reduced. Consequently, the design of the subjects and the support material must be periodically reviewed considering the own experience of professors and mentors, as well as the comments of the students.

Keywords: First-year university students, higher education, physics, propaedeutic.

1. Introduction

One of the main problems detected in the learning process of first-year university students of engineering degrees is the inhomogeneity of prior knowledge of mathematics and physics. This fact entails the need to generate and design complementary activities and learning material to achieve a higher level of performance for the group of students after the first academic year. One of the strategies is the design and implementation of propaedeutic Physics courses for those students with a low initial level in the subjects considered basic in engineering. For engineering studies, it is advisable to have some previous knowledge of Physics and Mathematics. Without this knowledge, first-year university students will easily fail first-year compulsory subjects (Burkholder, 2023) (Tsui & Khan, 2023), which leads to a significant dropout rate (around 30% in our engineering grades). It is shocking because when choosing an engineering degree, secondary school students applying for said degrees are expected to be those with high Physics and Mathematics performance (Tan et al., 2021). Unfortunately, one of the characteristics of the Spanish university system is that a significant number of first year students in engineering degrees have not taken Physics subjects the year (or two years) before reaching university. Thus, it is highly recommended and advisable to design physics courses of a propaedeutic nature. Therefore, these courses should be designed for students who have already enrolled in the university. It is different to those courses designed for pre-university level; such courses are prepared to detect those who can be good engineering students or to make a pre-selection of the most apt and prepared. For example, to discriminate between eligible and ineligible students during the propaedeutic phase of medicine and biomedical science study programmes (Etjsvogels et al., 2013). At present, problems are not only detected in first-year subjects; the problem is spreading to higher grades (Suárez et al., 2024). With respect to these courses success, one of the most important aspects linked to the success of the propaedeutic courses is the engagement of the students. This includes their willingness to work collaboratively in different scenarios, their ability to interact with their peers and teachers in a positive spirit, self-reflection on their learning process, development of a critical spirit and the capacity for analysis and synthesis (Ontiveros et al., 2019). In other words, both soft and hard skills. Evidently, the engagement of the academic staff is also necessary. MOOC courses have been introduced in recent decades (Estela-Carbonell et al., 2016). These courses should be considered complementary. The need for face-to-face interaction (teacher-student) has been noted to improve both engagement and performance.

In our study, propadeutic Physics courses have been implemented. The current courses are the evolution of those carried out over almost two decades. The students who act as mentors have been trained in previous sessions with the support of the academic staff. More broadly, propaedeutic courses should be extended to all subjects related to each specific STEAM domain to achieve this homogenization.

2. Objectives

The objectives of this study are to improve the Physics knowledge of first year students and to achieve an improvement in their academic performance. Consequently, drop-out rate is expected to be reduced and the previous cognitive deficiencies in Physics corrected.

It is expected that the propaedeutic courses help the homogenization of the Physics knowledge and the academic performance.

3. Methodology

The methodology used in this study consists of:
a) Design of two Physics courses intended for first-year undergraduate students of engineering degrees.
b) Generation of teaching material: Including summaries of theory, solved problems, videos and self-evaluation questions and problems.
c) Interaction of faculty and student mentors with students in the classroom and virtually.
d) Activity evaluation surveys with subsequent statistical analysis.
e) Monitoring of students' academic performance in compulsory Physics subjects.

The material is appropriate to the courses generated. One with content mainly on mechanics (kinematics, Newton's laws, work and energy) and the other on electromagnetism and circuits (electric and magnetic fields, direct current circuits). This division is justified by the existence of two compulsory Physics courses (one in each semester of the first academic year).

It should be noted that a decade ago, the number of students participating was in the order of 30 to 40. Over the last few years, the growth has continued up to 250-300 in the last two years. This fact is related to the growing interest of students in the complementary training offered by the university and to an increasingly lower level of Physics at university entrance (at least on average). This low level is also detected in mathematics and in aspects related to reading and writing.

4. Results and discussion

In this section we show some examples of the material generated for learning and analyze the academic success. The continuous interaction between the learners and the academic staff favors the improvement of the design of the subjects and the supporting materials are periodically reviewed to transform them into attractive resources for the students.

Figure 1 shows a problem that students encounter on the on-line platform. These problems are used to self-evaluate their learning. There are problems in which the specific data values are randomly varied and, therefore, each problem has multiple variables. On the other hand, students are provided with the theoretical foundations and solved problems (in pdf and video format). This material is also worked in face-to-face classes. One of the difficulties of this online learning is that the platform evaluates the result, not the resolution procedure. Consequently, face-to-face tests and exams continue to be necessary.

Figure 2 shows an image of a video in which a problem is solved. The interaction with the students has allowed us to improve the teaching material generated. It has been noted, especially after the pandemic, that students are becoming more visual and have more problems with reading and writing. As a result, they are more demanding in terms of the quality of the audiovisual material. Likewise, the statements of the problems and questions, as well as the theory, must be explained in detail.

There is a certain contradiction: on the one hand, there is a desire to have access to all teaching materials on the university's online platform, and on the other, face-to-face sessions with direct interaction with teachers and mentors are highly valued.

With respect to the students acting as mentors, these have been trained in previous sessions with the support of the academic staff. Obviously, there are students of the two last academic years (correct mathematics and physics knowledge). Their activity has been recognized academically through a scholarship (or sometimes as an internship for academic credits). The positive influence of mentors in the learning performance is analyzed in previous students (Daza et al., 2020) (Daza et al., 2023).

Figure 1. Example of problem (Energy section) designed for self-learning and self-assessment.

La figura ostra una caixa de massa m = 13 kg que llisca cap avall en moll de descàrrega. La longitud de la rampa és l = 3 m i està inclinada un angle de 29º. La caixa comença a lliscar des del repòs en la part superior i experimenta una fricció constant de F_f = 1,9 N. Mitjaçant conceptes energètics determineu la velocitat de la caixa al final del pla inclinat.
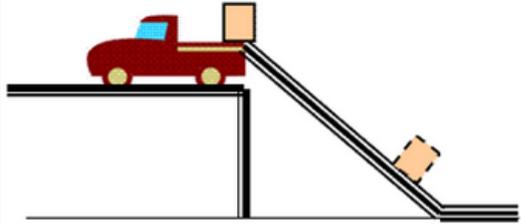

NOTA: Arrodoniu el resultat a dues xifres decimals.

Resposta:

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Figure 2. Image of a video (Energy section). Resolution of a problem.

Exemple 1:
Un electró i un positró entren en un camp magnètic uniforme de 2·10⁻⁴ T com es mostra en la imatge. Es demana:
1. Indica quina trajectòria seguirà cada partícula.
2. Si el radi de la trajectòria és de 5,8 m, troba la velocitat del positró, la velocitat angular, el període del moviment, la freqüència i l'energia cinètica de la partícula.
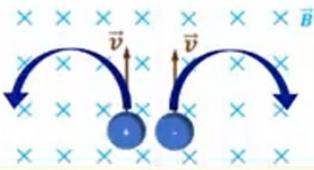
$$r = \frac{mv}{qB} \rightarrow v = \frac{rqB}{m} = \frac{5,8 \cdot 1,602 \cdot 10^{-19} \cdot 2 \cdot 10^{-4}}{9,11 \cdot 10^{-31}}$$

$$v = 2,04 \cdot 10^8 \, m/s$$

$$\omega = \frac{v}{r} = \frac{2,04 \cdot 10^8}{5,8} = 3,52 \cdot 10^7 \, rad/s$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{3,52 \cdot 10^7} = 1,79 \cdot 10^{-7} \, s$$

$$f = \frac{1}{T} = \frac{1}{1,79 \cdot 10^{-7}} = 5,60 \cdot 10^6 \, Hz$$

$$E_c = \frac{1}{2}mv^2 = \frac{1}{2}9,11 \cdot 10^{-31} \cdot (2,04 \cdot 10^8)^2$$

$$E_c = 1,90 \cdot 10^{-14} \, J$$

In addition, students are provided with links to external videos made by professors specialising in teaching Physics in an online environment. Those considered most appropriate are selected.

One of the secondary objectives is to make the courses more affordable and structured. Thus, the knowledge pills follow a structured format of timed teaching-learning sequences. Each sequence is made up of resources and different activities (questions, problems). The resources include both theoretical and experimental contents. There are designed to favor the diversification of learning depending on the specific characteristics of each student.

In the last year, two Physics courses have been designed in the OpenUdG platform. The main goal is to favor the access to this learning material to high-school students and professors. It has been detected that these courses have been well received by the pre-university educational community, as shown by the annual registrations for the courses (74 registered during the 2023-24 academic year). 73% of these registrations correspond to students intending to study a degree in engineering and the rest correspond to teaching staff at high school and further education level.

One of the problems detected in the learning of Physics in the pre-university field is that most teachers have not studied Physics. Consequently, their access to teaching material is facilitated to help them in their subjects and allow them to determine what level their students must have when they access engineering degrees.

Another aspect to be analyzed is that of formal evaluation. The following figures show the statistical analysis of the grades obtained in 2023 and 2023 in the evaluation of various topics. Specifically in the Physics course of the first semester.
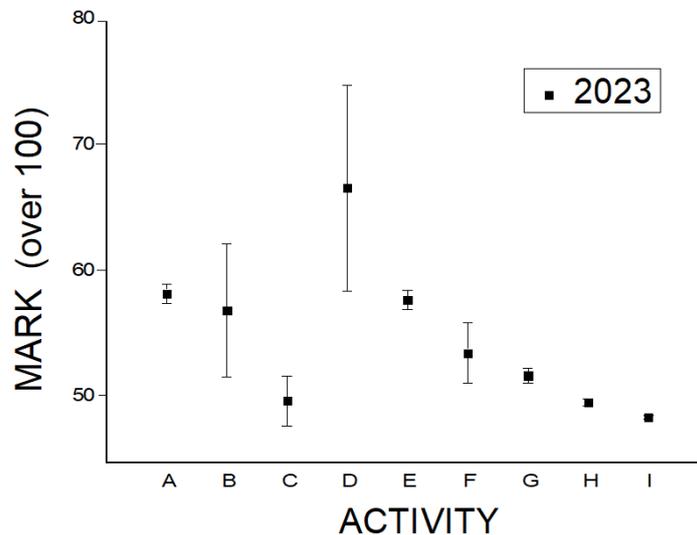
Figure 3. Marks (mean value and statistical deviation) of the 2023 assessment of several topics.
A: Kinematics (one dimension), B: Kinematics (two dimensions), C: Kinematics (general), D: First law of Newton,
E: Second law of Newton, F: Dynamics (circular motion), G: Work and Energy,
*H: Law of Conservation of the Energy, I: Energy variation.*

Figure 4. Marks (mean value and statistical deviation) of the 2024 assessment of several topics.
A: Kinematics (one dimension), B: Kinematics (two dimensions), C: Kinematics (general), D: First law of Newton,
E: Second law of Newton, F: Dynamics (circular motion), G: Work and Energy,
H: Law of Conservation of the Energy, I: Energy variation.
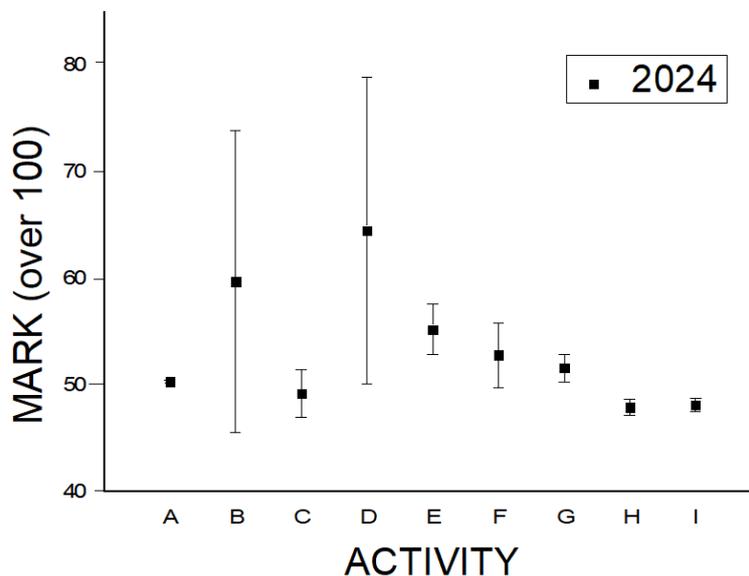
Several trends are detected. In both cases, the grades are mostly positive, the best average grade is related to the application of Newton's first law and the worst results are obtained in the topics of conservation of energy or in problems of variation of energy (the last of the first preparatory course). The segmented evaluation causes more work for the teaching staff, but makes it easier to detect in which concepts or applications the students have greater cognitive problems. A detailed analysis allows in subsequent courses to focus more on the concepts that the students show more difficulty.

The majority of students (over 90%) pass these courses. As already pointed out, student engagement is essential to achieve these results. These courses encourage students with a lower initial level to drop out of university studies at a lower rate. Historical data show high dropout rates and a high

percentage of students who complete their studies in 2, 3 or more additional years. In other words, an engineering degree structured in four academic years was completed after 6 years or more.

For these courses to be useful, another of the procedural objectives is that their final level resembles that of the rest of the students. The detailed analysis of the grades of the compulsory Physics subjects shows that this is the case. It has been detected that the percentage of students who end up passing the subject that same academic year is around 50-70% higher than before and the percentage of success is similar to that of the students with an initial correct knowledge of Physics.

5. Conclusions

This study has shown that well-designed and correctly implemented propaedeutic courses in Physics is a clear option to improve the academic performance of first-year undergraduate students of engineering degrees with a low initial level of Physics. On the other hand, an adequate segmentation of the contents, their evaluation and the interaction with the students allow for a continuous improvement of the teaching material generated. The results show that the majority (>90 %) of the students involved pass the basic subject and that the percentage of students passing the compulsory Physics subjects is like the percentage of students with an acceptable initial level of Physics. Moreover, it has been found that the number of students following these courses is increasing (from 30-40 to the current 250-300), being an indicator of the decreasing average level of physics-mathematical knowledge with which new students enter university, even in engineering studies. In addition, online courses have been created for pre-university students and teachers.

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