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Development of scientific skills in Higher Education with a flipped classroom-contest approach

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Abstract
In this work, the flipped classroom methodology has been applied to the laboratory sessions in the subject Physical Techniques I of the Degree in Physics at the University of Zaragoza, Spain. The proposed sessions have been distributed in two main parts. The first part consists on flipped laboratory sessions in which during the before-class sessions, the students must understand, design and customize the designs that will have to characterize experimentally in the laboratory sessions. The second part consists of a student contest activity where the students compete against their pairs while improving their learning about the topics presented in the flipped classes. The proposed approach could increase the depth of the acquisition of experimental skills, helping students to acquire a better understanding of the concepts under study in laboratory sessions.

Keywords: *Active learning; collaborative work; flipped classroom; laboratory skills; model-based learning.*

1. Introduction

Model-based learning is the construction of mental models of phenomena by integrating information about their structure, function and causal mechanism, and mapping that information into analogous systems (Gobert and Buckley, 2000). A model can be seen as a representation of a target and serves as a “bridge” connecting a theory and a phenomenon (On and Oh, 2011). If we consider the classical approach of Gilbert (1991), models are built by an induction process based on simplified representations of systems. Teaching of physics (and engineering) has traditionally focused on the development of a conceptual understanding of the relations between the contents, laws and principles of the matter. Physics education research has uncovered serious difficulties in learning (Duit, 2009) because of the lack of models that emphasize the construction of knowledge (Ceberio et al., 2014). Nowadays, model-based learning is becoming an essential part in the evolution of the strategies in science teaching. Despite the difficulty of knowing the nature and content of the mental models of students, instructors can design different strategies to address and evaluate them. In this paper we introduce the flipped classroom as a relevant instructional strategy.

The flipped classroom is a pedagogical method that transfers certain learning processes outside the classroom and uses class time to facilitate and enhance other processes of acquisition and practice of knowledge (Wang et al., 2018; González-Gómez, 2017). It promotes autonomous learning and also frees classroom time to carry out active activities in which participation and the exchange of ideas are promoted. From a model-building point of view, students are encouraged to become more personally involved in their construction, while at the same time the necessary conditions for these models to be contrasted and discussed with their peers are promoted. As a consequence, a flipped classroom has to be a comprehensive approach that combines direct instruction with constructivist methods with the main objective of increasing student engagement and involvement in the course content to improve their conceptual understanding.

In this work, we propose to apply the flipped class methodology to the experimental part of the compulsory subject Physical Techniques I of the Degree in Physics at the University of Zaragoza, Spain. Adding to the advantages of active learning, the flipped classroom allows to dedicate more laboratory time to apply knowledge acquired using active learning strategies, and therefore the learning process can be better followed by the teacher.

2. Proposed Teaching Methodology

The classical interpretation of model-based learning engages students in an iterative process oriented to build a mental model of a given phenomenon. There are many ways to achieve it such as inductive processes, simplifications, comparisons, integration of information, etc. (Cascarosa, et al., 2020). Although model-based learning needs to be carried out by the students, the instructors can adopt strategies to facilitate the acquisition of the models, and to assess that they have been built correctly. It is in this scenario where the flipped classroom methodology is applied, allowing to create an environment of collaborative learning in the classroom, and involving the students from the beginning in their own learning process. By the application of a methodology based on the flipped classroom, the authors expect to contribute to a correct development of mental models by the students.

2.1. Participants and scope

Participants are the students enrolled in the course Physical Techniques I, which aims to provide basic skills in metrology and electronic instrumentation for the measurement of physical magnitudes. In Physical Techniques I, students must be able to analyze basic electronic circuits, determine specifications and tolerances for a measurement, and design the full setup to carry out a measurement, calculating the contribution of every stage to the uncertainty. The theoretical contents of this course have a weight of 4 European Credit Transfer System (ECTS) credits while the experimental part has a weight of 2 ECTS credits. The experimental part of the course is divided in four laboratory sessions: the first session is introductory and intended for students to become familiar with the measuring instruments; the second session teaches students to analyze the stationary and transient behavior of resistor-capacitor (RC) and resistor-inductor-capacitor (RLC) circuits; the third session studies experimentally the behavior of several circuits such as a non-inverting amplifier and a comparator, and the last session deals with filtering and signal conditioning. The basic concepts and lab procedures are previously explained during the theory blocks, which take place before the laboratory sessions.

In this course, students face the basic concepts of Electronics and, in particular, Circuit Theory for the first time. Furthermore, the laboratory sessions require the use of several instruments that students are not used to manipulate. As a consequence, students often need guidance by the instructors, which leaves less space to implement active learning activities.

2.2. Example of application

Traditionally, before the realization of a laboratory session, students receive a theoretical-practical explanation about the goals and the procedures to be followed. Subsequently, during the session, they have access to specific supporting materials (instrumentation user manuals, component data sheets, etc.). Also, the instructors, present during the sessions to help in the realization of the different tasks, have to deal with several groups simultaneously, making it difficult to provide an immediate and comprehensive answer to all questions raised by the students. The proposed flipped laboratory sessions are distributed in 2 main parts.

1. Flipped Laboratory. Before the laboratory sessions, the students are given the designs and their intended application. With the help of electronic simulation software, they must

understand the designs, choose some parameters to make them work as intended and, finally, verify the correct operation of the final designs. During the laboratory sessions, the students have to implement the designs with commercial components and characterize them experimentally, comparing the results with those obtained by simulation. The main idea of this part, which will be more deeply explained afterwards, is to introduce students to the standard design-simulation-characterization process typically used by electronic designers.

2. Student contest. This practice is planned as a very dynamic activity where the students compete against their pairs while improving their learning about the topics presented in the flipped classes. This activity is divided in two sessions: an initial one based on solving a real problem using Toolkit for Interactive Network Analysis (TINA) simulations, and a second one consisting on a quiz. Unlike the flipped laboratory, which is an experience that has already been carried out, the student contest is an activity that we have newly introduced in the current course, where we have applied it to the second laboratory session to obtain preliminary results. If these results are satisfactory as it is expected, the approach will be extended to all laboratory sessions in future courses.

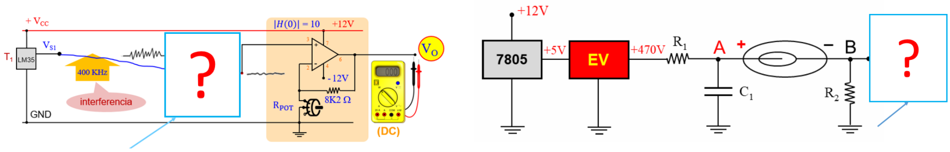
3. Proposed experience

During the before-class activities, the students, divided in groups of 2 or 3 depending on the total number of students enrolled, have access to different materials and references related with the topics of study as well as to an explanation of the main concepts covered. They are encouraged to refer to other subjects such as electromagnetism to ensure a good link with the previously study topics. Also, they have some references to look for the main figures of merit and performance criteria of the system under study. Although some main references are provided by the instructors, the students are encouraged to look for related information and references. The students have to carry out TINA simulations of some performances. For this purpose, they have access to different tutorials, explicative videos and manuals of how to use this software. TINA is a SPICE-based electronic design and simulation software. In the laboratory session, the students will use the free version TINA-TI offered by Texas Instruments. The groups have access to the material two weeks before the laboratory session. But the instructor is going to acquire the role of mentor supervising and assessing in the preparation of the flipped class. Therefore, as a minimum, one week before the laboratory session, a meeting between the teacher and the groups is planned so that students can explain the development of the work they are doing as well as to ask for help with the organization of the flipped class and the bibliographic search. During the laboratory sessions, the students must experimentally characterize the circuits that they have previously studied and simulated.

The circuit that they have to characterize experimentally, the RLC circuit in the session 2, is the one that combines the two concepts: a circuit in which two energy storing elements exchange energy periodically, and also a circuit in which an energy dissipating element (the resistor) gives out a part of the total energy in every oscillation cycle. Also, the operation of this circuit can be linked to that of mechanical damped oscillations, so that they can relate with all aspects covered in courses on Mechanics about the actual damped oscillating frequency versus the undamped frequency (that of the LC circuit) and the ratio of energy lost per cycle, which is given by the quality factor Q.

To conclude the flipped class activities and also as a way to promote the interest of the students in the presentations of their colleagues, we propose to perform a student contest. This contest consists of two classroom sessions in an interactive classroom where each student can win extra points (half of them in each student contest session) for the total grade of the course. This special classroom contains some television screens with their respective cooperative tables and a main bigger screen with a projector. Making use of the MirrorOp Sender application, the students can connect their devices to the TV screens to benefit the collective work and the share of information and in this way, everyone in the group can easily see what the others want to show. The teacher has access to all the screens of the room so that he/she can show in the main big screen some interesting information of some groups that can be useful for the rest.

For the first session of the student contest, the students have to solve a case study using all the knowledge they obtained in the flipped classes. In particular, it was found convenient that students made use of TINA simulations to solve the case study. They have one hour to read and solve the case with the help of all the tools and information they have available in their computers, the material of the course uploaded in the Moodle Learning Platform and the Internet. As a deliverable, at the end of the session, the students have to send to the teacher a slide with a summary of their solution of the problem. In the last minutes of the class each group has to present and defend their work. The teacher is in charge of deciding which work was the winner to give the group the extra points. In one case study, the students are given a design which consists of a temperature detector connected to an amplifying stage which output will be proportional to the temperature. The student must propose a solution to mitigate the output error by high interferences in the wire connecting the sensor with the amplifier. Several possible signal conditioning circuits are given to the students and they have to choose the appropriate circuit. In other, the students are given a radiation detector contains a Geiger-Muller tube, which produces an instantaneous current pulse when a particle passes through it. This current decays rapidly in the absence of new particles. The students must include an additional circuit that manages to make the presence of the particle visible by prolonging the duration of the voltage peak supplied by the detector. In a similar way as in the previous case of study, the students are given several possible circuits and they must select the appropriate one and integrate everything in a final design (Figure 1).



(a) *(b)*

Figure 1. Scheme of systems where the students must include a circuit in (a) temperature (b) radiation detector.

The second session of the student contest consists on a quiz that contained different questions related to the flipped classes. To solve the questions, the students have free access to all the material of the course. To guarantee the collaborative objective of the session, the students only have access to one question of the quiz at a time and they cannot come back in the quiz. At the end of the quiz, the students know their punctuation but not the specific questions that they answered right or wrong. In this way, they have to decide whether or not they want to try to solve the quiz again as the winner is the group with more right questions when the time ends. For this second session the students have one half hour to solve the quiz. The rest of the class is left for the teacher to explain the main solutions to the questions of the quiz and debate with the students their solutions.

4. Assessment

To evaluate how the flipped classroom influences the learning outcomes and the construction of the knowledge model, the assessment of the students is divided in several actions along the course. Among the evaluation actions designed, we can cite specific quizzes, laboratory papers or talks containing information on the studied systems, their operating principles and related relevant information. Working through these resources, student must be able to construct his model and to check and assess his knowledge model.

The assessment of the activity has been focused on two main points. The evaluation of the quality of the resources created by the students and their performance in the flipped class as well as their performance in the student contests. And personal motivation and satisfaction of the students. To investigate how effective the tandem learning outcomes-flipped classroom is, a series of specific evaluation activities have been programmed both in the pre-class activities and in the face-to-face (F2F). A battery of quizzes associated with the use of simulation tools and applets in pre-class activities has been designed, which not only reveals the degree of understanding of the topics covered but also how they have been carried out, one of the bases of the flipped. In addition, both the learning and follow-up resources generated can be downloaded to any device, making it possible to do them anywhere and allowing a flexible learning environment. Another series of issues associated with F2F activities are associated with verifying both the associated specific learning outcomes and the effectiveness of these self-study sessions.

The evaluation of the laboratory sessions is done attending to skills that students are expected to develop along the course. The skills encompass technical aspects such as the implementation of the experimental set-up, the measurement process, and also behavioral aspects such as student autonomy and attitude, time spent, or the elaboration of the final report. The assessment of the skills related to the assembly of the instrumentation is carried out by a questionnaire before the laboratory session, together with viewings of videos of handling the devices. Finally, the assessment of the skills related to the communication of the results is carried out by a report that students have to hand out within the following days after the realization of the lab session (Sánchez-Azqueta et al., 2019). To evaluate the experience and motivation of the students, a specific survey has been created since evidence suggests that there exists a strong correlation between student motivation and satisfaction, and the success of virtual learning activities. To validate the effect that the inclusion of the flipped classroom has on the results of the students enrolled in the course under study, a comparison should be carried out with the grades obtained by students during the academic years when it was not already implanted, but the strategy presented in this work has been performed in a current academic year.

5. Expected results and Conclusions

This work presents the use of flipped classrooms combined with the student contest as a pedagogical tool to implement model-based learning in higher education. In spite not having final results yet, some advantages over the traditional approach are expected using this methodology, such as increased student motivation and autonomy, or a deeper understanding of difficult concepts (Gilboy et al., 2014). In addition, it encourages the use of specific recourses to support the study of the topics and to acquire a deeper understanding of these processes, improving student motivation (Chen et al., 2014). The flipped classroom allows more time for active learning to happen in the classroom, further they develop a collaborative work in a realistic environment, which fosters their learning autonomy and active, participative teaching, promoting the conditions leading to the establishment of peer learning. In summary, the methodology proposed in this work allows students to map the different pieces of information into a general system to develop their own mental model.

In this respect, it can be considered that while non-interactive resources are more convenient to present the topics and main ideas, interactive resources are more powerful to establish links between them to build the models (Sánchez-Azqueta et al., 2016), and to check whether the conclusions drawn from the models are true (O´Flaherty and Phillips, 2015). A process is created so that students engage in the development of the mental models of the topics covered in class with tools aimed for facilitating their construction and also assessing their correctness. The implication of every student is required for this process and therefore fosters their learning autonomy, but also the exchange and social cooperation with their peers to analyze their own knowledge models, which entails sharing hypotheses, amending their thoughts and working with their cognitive disagreements.

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